MECHANICAL ENGINEERING

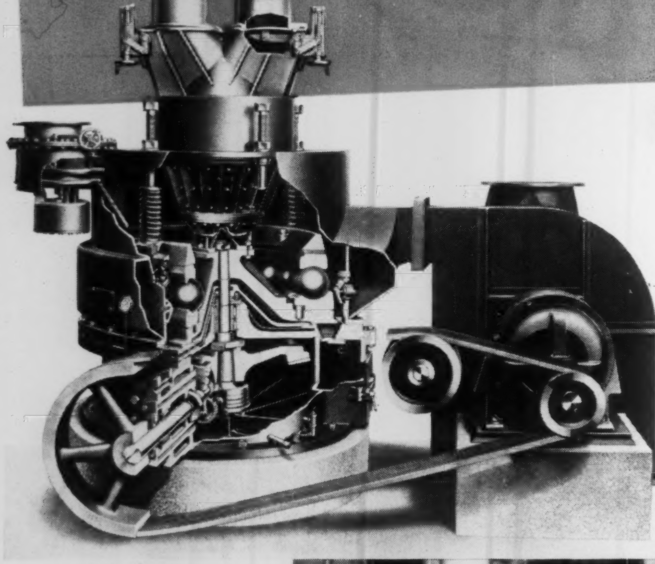
May 1943

OFFICIAL NAVY PHOTO

The B&W Type E Pulverizer

Fits into Any Day's Fuel Picture

Operates reliably and effectively in direct-firing pulverized-coal systems



Type E Pulverizer with pulverizing elements and fines classifying elements in upper section and driving elements in lower section sealed and protected from coal dust. Primary air fan, which handles clean air only, is generally driven by same motor that drives the pulverizer.

By every standard of direct-firing pulverizer performance, the Type E Pulverizer fits into the fuel economy picture any day, and especially so during the present emergency requirements.

Type E Pulverizers—

- Are reliable in service and low in maintenance, as measured in service hours before replacement of parts becomes necessary.
- Respond readily to load changes—output controlled at one point, the primary air damper, and are adaptable to fully automatic control.
- Maintain fineness and capacity throughout life of grinding elements.
- Handle coal of a wide variety and, due to drying in the mill, can handle coal with as much surface moisture as it will carry.

These and other features of the Type E Pulverizer are given in more detail in Bulletin G-30-A. Copies obtainable on request.

THE BABCOCK & WILCOX COMPANY
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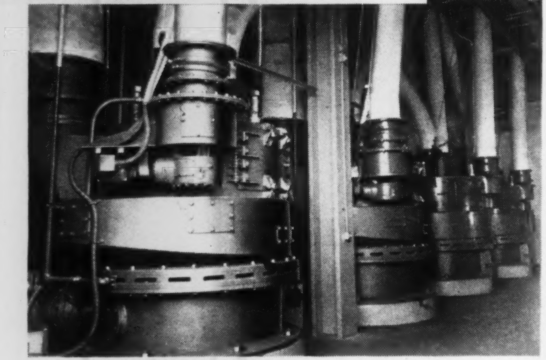
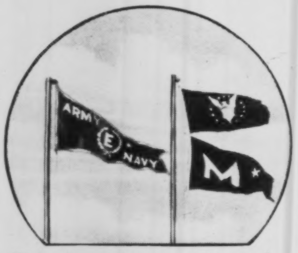
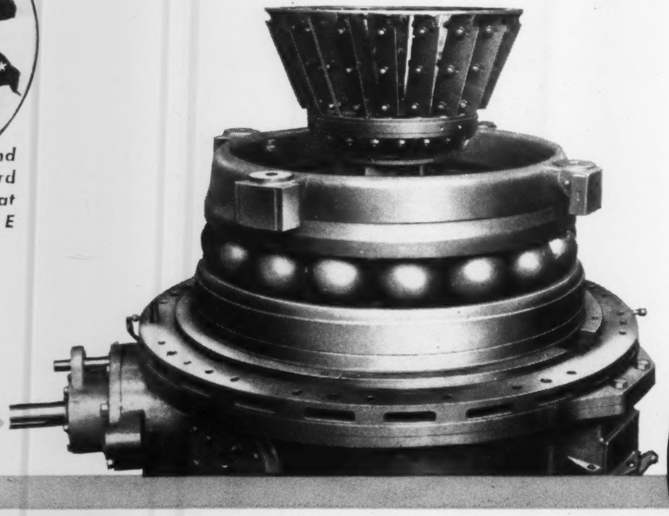


Over 400 Type E Pulverizers are in service or on order for direct firing boilers. Individual installations have as many as 16 units.



The Army-Navy "E" and Maritime Commission Award flags are floated proudly at the plant that builds Type E Pulverizers.



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G-244

MECHANICAL ENGINEERING

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The Air Force Wages Global Warfare

(Col. William H. Tunner, commanding officer, Air Transport Command Ferrying Division, Col. Thomas Mosley, commanding officer, Alaskan Wing, ATC, and Major General Harold L. George, commanding general, ATC, studying great-circle routes to speed delivery of men and munitions to fighting fronts.)

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No. 5

MECHANICAL ENGINEERING

MAY
1943

GEORGE A. STETSON, *Editor*

Another A.S.M.E. War Job

As announced in the report of the March 26 meeting of the A.S.M.E. Executive Committee (see page 382) The American Society of Mechanical Engineers has set up a Manufacturing Engineering Committee at the request of the Office of Production Research and Development and has signed a contract which covers the relationship of the new committee with O.P.R.D. and the financial subsidy under which the committee's activities will be conducted. L. C. Morrow has accepted chairmanship of the new A.S.M.E. committee. Serving with him will be Harold V. Coes, Fred H. Colvin, Eric Oberg, and Col. James L. Walsh.

As executive secretary of the new committee, Herbert B. Lewis, member A.S.M.E., of Providence, R. I., has been engaged by the Society. Mr. Lewis has recently come from an assignment with the National Research Council and has been granted a leave of absence from the Brown & Sharpe Manufacturing Co. to undertake this important work. His headquarters will be at 40 West 40th Street, New York, N. Y., in the American Radiator Building which backs up to the Engineering Societies Building on 39th Street. Choice of New York as headquarters of the new committee's activities was influenced by proximity to the A.S.M.E. offices and the Society's facilities for quickly getting in touch with engineers in lines of work likely to be useful to the committee.

In an editorial in the December, 1942, issue of MECHANICAL ENGINEERING the principal functions of the Office of Production Research and Development, which is headed by Harvey N. Davis, past-president, A.S.M.E., and president, Stevens Institute of Technology, were stated as follows:

1 To provide the chairman with technical information on problems with which he is directly concerned and on research and development work now in progress in W.P.B. The office is also to provide the W.P.B. divisions and branches with research information and findings on work which they have in progress.

2 To initiate evaluation and analysis of specific scientific or technological proposals, through the establishment of expert committees or through reference to existing research groups in government, education, or industry.

3 To get needed research accomplished by contracting with outside laboratories or agencies for experimental work.

4 To bring about development of such projects or processes as are found to merit it through contracting for the construction of prototypes or the erection of pilot plants.

The A.S.M.E. Manufacturing Engineering Committee will concern itself with specific problems referred to it by O.P.R.D. in such fields as production research, processes, manufacturing techniques, and materials. It is not concerned with patented inventions and their development. A panel of investigators will be set up in the fields to be covered and the committee will refer to the appropriate group of investigators the subjects passed on to it by O.P.R.D. The findings of these groups of investigators will be reported as quickly as possible to O.P.R.D.

In setting up the Manufacturing Engineering Committee The American Society of Mechanical Engineers has initiated a direct and authoritative channel of contact between the O.P.R.D. and the best talent of the mechanical engineering profession. Some projects are already under way and more will follow as the organization Mr. Lewis is building up swings into its stride. That the A.S.M.E. has been chosen to carry on this important work is a recognition of the value of its services on behalf of the war program in many fields and its traditional role of disseminating engineering knowledge, for it is understood that the results of the committee's investigations will be made available by O.P.R.D to any manufacturer who may have need of it in his war work.

A. L. Kimball

In the sudden death on March 20 of A. L. Kimball, fellow A.S.M.E. and research physicist and consulting engineer of the General Electric Company, The American Society of Mechanical Engineers lost another distinguished member who had served it faithfully. Mr. Kimball had just completed a five-year term on the Committee on Meetings and Program, during the last year of which he had served as chairman. During that year the war brought serious problems to the committee. Intense activity of all engineers in war work, congestion of travel routes and hotel accommodations, difficulties in getting the release, for presentation and publication, of information needed by our own engineers but of equal value to the enemy raised the question as to whether engineering meetings could or should be conducted in wartime. Events proved that attendance at meetings increased markedly; and there was no dearth of useful papers, although planning was difficult because of last-minute changes and additions to the programs, and an abnormally large percentage of papers was received too late for preprinting. In spite of these unusual hazards and burdens Mr. Kimball and his committee conducted some of the most successful meetings in the history of the Society. This feat has placed all mechanical engineers in debt to Mr. Kimball.

Arthur Kimball typified a group of engineers that is growing in numbers and importance, a group that is serving to bridge the gap which exists between applied science and theory and the fields of design, construction, and practice. His father's name became well known to thousands of engineers because of a widely used textbook in physics, two editions of which the son edited after his father's death. With an academic and scientific background, Arthur Kimball spent his early years in graduate studies, in engineering practice, and in teaching, laying the foundation for a comprehensive knowledge of physics and mathematics which proved so useful in his work with the General Electric Company, which began in 1918. Sent to England in 1919 to study the new subject of photoelasticity under Dr. Coker, Mr. Kimball returned to Schenectady where studies of the causes of turbine-wheel vibration resulted in the elimination of practically all failures from this cause. His work on problems of noise isolation, mechanical unbalance, vibration damping, and stress analysis by means of polarized light enriched the literature of these subjects and greatly aided in the design of rotating machinery.

Mr. Kimball was long associated with the A.S.M.E. Applied Mechanics Division and assisted in building up the international reputation which that group has justly acquired. He had the quiet manner of a scholar and the analytical mind of an engineer. That he found time and had talent to serve the A.S.M.E. on one of its most important administrative committees is an indication of the breadth of his interests and abilities.

"The Engineering Journal"

CONGRATULATIONS are in order to our contemporary across the border, *The Engineering Journal*, monthly publication of The Engineering Institute of Canada, which is celebrating its twenty-fifth anniversary.

Although the Institute was founded in 1887, it was not until a quarter century ago that *The Engineering Journal* was brought into existence as a medium for bringing engineering papers and Institute news to the engineers of Canada. In that quarter century the journal has kept pace with the growth of engineering in Canada and the membership of the Institute.

Unlike engineering societies in the United States, The Engineering Institute of Canada serves the entire engineering profession of the Dominion. On the basis of population, the Institute is larger than the combined Founder Societies of the United States. These members are spread out over a relatively narrow strip of country lying just north of our border and more than 3000 miles long; *a mari usque ad mare,* as the armorial bearings of the Dominion phrase it. The task of holding together the interests of engineers so widely separated is accomplished by local organizations and *The Engineering Journal*. The Journal, therefore, supplies the need of a means of publishing technical papers covering a wide field of technical interests and also a medium through which news of the numerous local groups can be brought to the attention of all. This diversity of interest, technical as well as professional, makes the Journal unique among engineering periodicals on this continent.

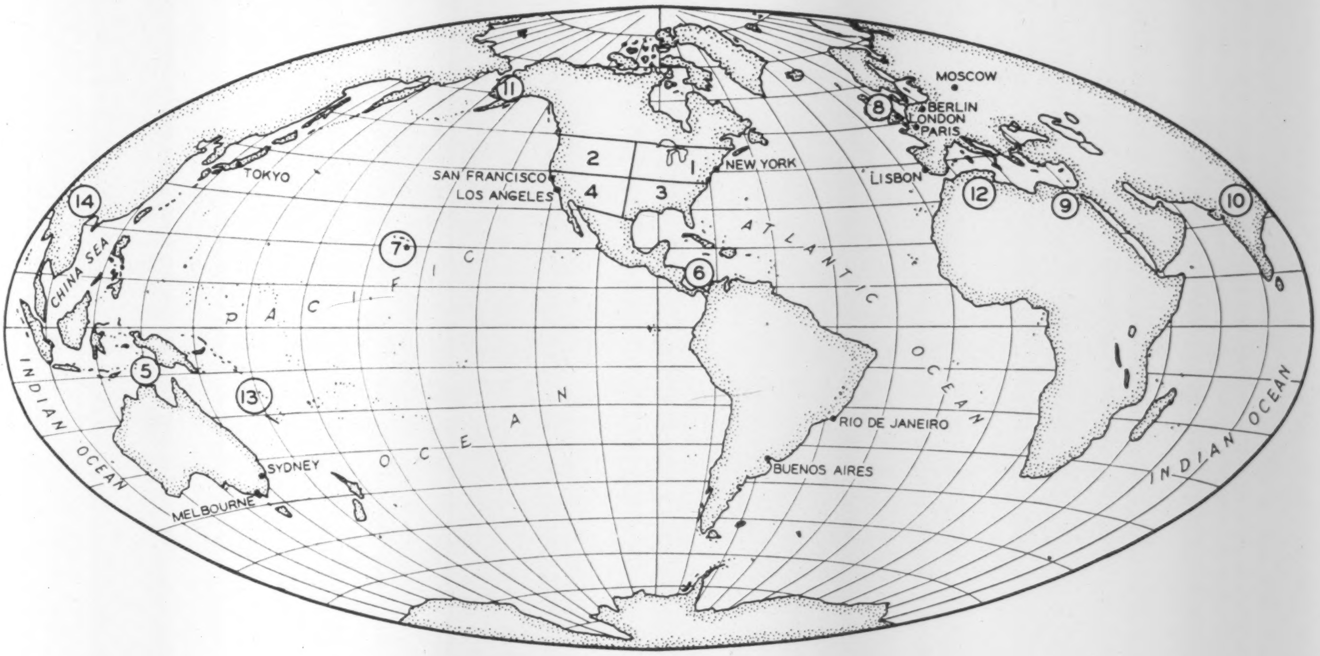
During the last quarter century the development of engineering in Canada has been rapid and varied. The war is accelerating engineering, and particularly industrial, developments. With close ties to Great Britain and the United States, Canadian engineers have made an enviable record for themselves. Possibly because they are grouped in a single professional society, they appear to exert a more powerful influence with their government than engineers do in this country. This condition is not fortuitous; it arises from qualities of leadership and service and a dominant professional organization which they possess.

Relations between The Engineering Institute of Canada and The American Society of Mechanical Engineers are becoming closer every day. Bound with ties of a common language, generations of amicable relationship across an unguarded international border, dedication to a common cause in the present war and to common ideals and methods of workmanship in times of peace and war, the engineers of these two great societies look forward to even greater friendship and co-operation. With the coming of peace, the reconstruction of the world, and the advancement of the engineering profession, may *The Engineering Journal* continue to grow in usefulness and influence, to the greater glory of the engineers of Canada.

A New Quarterly

UNDER the leadership of Dean R. G. D. Richardson, Brown University has attracted a group of scholars whose work lies in the fields of applied mathematics and mechanics and has set up courses in these subjects in its graduate school which have been given wide attention. As a natural consequence of the work of these mathematicians, Brown is now sponsoring the *Quarterly of Applied Mathematics* to afford a needed outlet for the publication of papers in this field.

Because The American Society of Mechanical Engineers publishes the *Journal of Applied Mechanics*, the founders of the new *Quarterly of Applied Mathematics* laid their plans in close co-operation with the Society. On the editorial board of the new quarterly are men who have been active in the A.S.M.E. Applied Mechanics Division. At the request of Brown University, the A.S.M.E. has appointed an official representative on this editorial board in the person of John M. Lessells, technical editor of the *Journal of Applied Mechanics*. Between the Journal and the Quarterly there exists the friendliest of feelings as a result of this appointment. Dr. W. Prager, managing editor of the Quarterly, and Mr. Lessells, editor of the Journal, have clearly defined notions of the scope and purpose of their respective publications. Manuscripts submitted by authors to either one of these publications will be referred to the other if the subject matter and method of treatment indicate such transfers are desirable. Thus it is conceivable that papers which the Applied Mechanics Division has been forced to reject because emphasis was on mathematical technique rather than engineering application will now find another channel for publication. Both the field of applied mechanics and that of applied mathematics will be better served in the future than they have been in the past.



ARMY AIR FORCES WENT GLOBAL WITHIN A FEW MONTHS OF PEARL HARBOR
(*Redrawn from a map prepared by Richard Eder Harrison for the Pan American System.*)

PROBLEMS *of* GLOBAL AIR WAR

By NATHANIEL F. SILSBEE

LIEUTENANT COLONEL, AIR CORPS

SEVERAL years ago Dwight Morrow in his report to Congress on military aviation said, "The next war will begin in the air, but it will end in the mud." It began in the air all right, as the *blitzkrieg* on Poland and the sneak attack on Pearl Harbor demonstrated. Within eight months of this event the U. S. Army Air Forces were engaging the enemy in the air on nine widely scattered fronts, with North Africa added three months later—more fighting fronts than any other organized military force in history. Naval and Marine airmen were also slugging it out over vast areas of the Pacific, 5000 to 10,000 miles or more away from home.

THE WAR IS GLOBAL

It may be a help to pick up the threads and indicate briefly how the Army Air Forces went global in such short order. You may recall that under the Air Corps expansion program in the fall of 1940 the GHQ Air Force (the combat branch of Army aviation) was divided into four parts, corresponding to the four field armies of the ground forces. These later became the first four Air Forces for the defense of the northeast, northwest, southeast, and southwest sections of the United States. Each was commanded by a brigadier or major general. Lieutenant General Arnold became Deputy Chief of Staff for Air, then in March, 1942, Commanding General, Army Air Forces. After notable air victories during the winter of 1942–1943 and indications of its growing importance in Europe, North Africa, China, and the South Pacific, he was made a four-star general on March 19, 1943.

As the world crisis became more acute, particularly in the Pacific area, the 6th Air Force in the Caribbean-Canal Zone area, and the 7th Air Force in Hawaii were strengthened. Alaska, for decades recognized by our leading air officers as highly strategic, received the nucleus of what later became known as the 11th Air Force, with air transport playing a vital part in achieving the results.

When the Japs struck, as part of their surprise party they grabbed Guam, and that cut our stepping-stone airway across the Pacific. We had to develop another aerial highway and establish bases in the South Pacific islands and Australia. Within a few weeks of Pearl Harbor we began reading of long-range bomber raids on Jap shipping from these bases. The bomber group based on Australia and New Guinea was the nucleus of the 5th Air Force under Lieutenant General Kenney, and the air elements in the South Pacific islands were greatly strengthened after our attack on Guadalcanal and became the 13th Air Force under Lieutenant General Harmon.

Early in March, Major General Brereton, who had been commander of our air force in the Philippines, took one of the remaining heavy bombers and a handful of officers and men to India as the nucleus of the 10th Air Force, to build up air strength in India as a base for smashing Japan from forward airfields in China. With the loss of the Burma Road in April, the India-China ferry route was opened up to fly in urgently needed supplies to Yunnan province over the 16,000-foot "hump," the toughest air route in the world. Brigadier General Clayton L. Bissell became Commanding General of the 10th Air Force in July and was made a Major General in March, 1943.

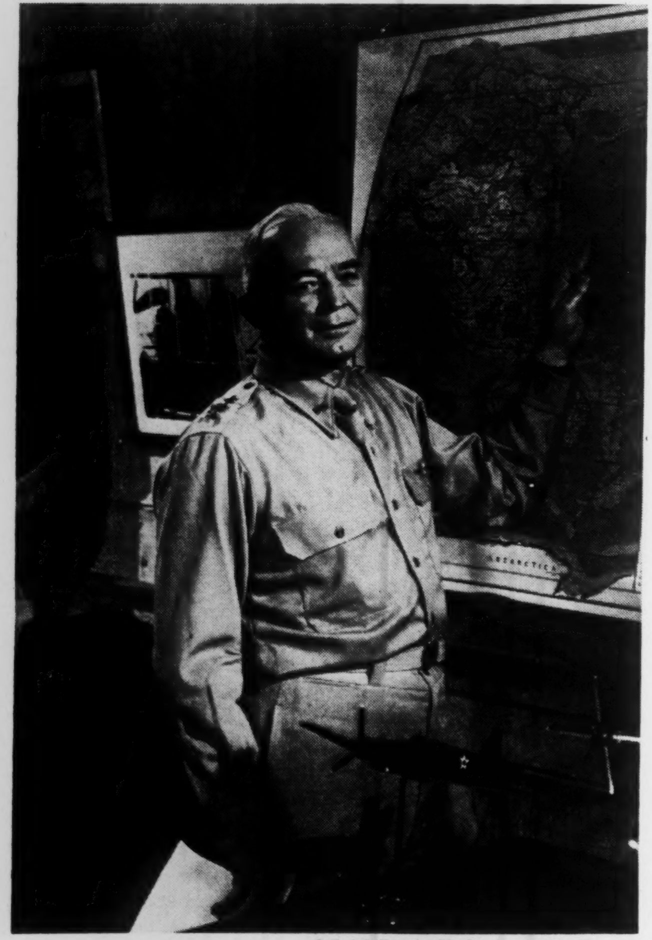
Colonel Claire Chennault's American Volunteer Group of

Contributed by the Aviation Division and presented at the Spring Meeting, Davenport, Ia., April 26–28, 1943, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

"Flying Tigers," organized in the autumn of 1941, was in there pitching almost from the day of the first Jap attacks. Their amazing record during the next six months with limited equipment is one of the epics of the war to date. Late in June the Army set up a China Air Task Force, with a fighter command and bomber command, under Chennault, soon to become a brigadier general in the Air Corps. These boys have made it plenty hot for the Jap fliers in China, and early in March, 1943, the outfit was activated as the 14th Air Force on a rising tide of official statements that more aerial aid for China would be forthcoming, and Chennault was made a Major General.

As part of the plan which culminated in the North Africa coup, General Brereton flew from India to Egypt in July and set up headquarters of the 9th Air Force (Middle East). Bases had been established and soon a substantial flow of American planes to this area was in effect, greatly aided by the air route across Africa. The 9th Air Force and the R.A.F. Middle East Command became the Western Desert Air Force and had a vital part in rolling the Afrika Korps out of Egypt and Libya. In November the other half of the air pincers came into place with the setting up of the 12th Air Force in Algeria-Tunisia. With part of Air Chief Marshal Tedder's Royal Air Force this is now known as the Northwest African Air Force, under the operational command of Lieutenant General Spaatz.

In July, General Spaatz had set up the 8th Air Force in England, with Major General Eaker in charge of the Bomber Command, under whose direction the first eye-opening heavy bombing raids by daylight over Europe were carried out. When Spaatz went to Africa, Eaker took over command of the 8th, and Lieut. Gen. Frank Andrews, one of America's ablest air officers, was appointed over-all commander of the European Theater of Operations. In accordance wth his first published statement this indicates a greatly intensified bombing of Germany. The big raids on Emden (Feb. 6), Rennes (March 3), Hamm (March 4), the highly successful raid on the submarine works at Vegesack (March 18), and the third heavy raid on Wilhelmshaven (March 22) are early examples of this stepped up activity.



Official Photo, U. S. Army Air Force

GENERAL ARNOLD EXPLAINING SOME OF THE DIFFICULTIES OF GLOBAL WARFARE TO A GROUP OF PROMINENT AUTHORS

LIFE LINES FOR VICTORY

The greatest single reason for this remarkable spread of American air power within a few months is the phenomenal growth of the Air Transport Command. Taking advantage of the vast pioneering experience of Pan-American, and ably assisted by many of our domestic air lines, the ATC, under Major General George, has developed four great airways and in terms of distance and volume of traffic has become the world's biggest air line. The four routes are the North Atlantic to England; the South Atlantic to Africa, via South America; and from Africa to Iran, India, and China; the South Pacific to our island bases and Australia; and northwest to Alaska.

Over these airways hundreds of transport and cargo planes are daily carrying men and munitions, parts and supplies for our round-the-world air force and for other fighting units. Victory-shaping policy at a Casablanca conference, a quick look-see by General Arnold and Admiral Nimitz in the South Pacific, a 35,000-mile trip by General Arnold to England, Africa, India, China—all become possible in a matter of days by the use of this modern strategic weapon, the air transport plane. The joint award of the Collier Trophy for outstanding aviation achievement to the Army Air Forces and the air lines of America is a testimony to this vital development of 1942. No fighting front is more than 50 or 60 hours distance from any other front or from the home bases.

Setting up these aerial life lines was problem No. 1, and it is no exaggeration to state that it has been met with characteristic American ingenuity; "impossible" obstacles and difficulties having been hurdled with an energy and determination which must have caused no little dismay to the Axis camp. Without them Suez and the Middle East on the one hand and Australia on the other would almost certainly have gone by the board, China and Russia isolated, and the war as good as lost. Time was gained to build up and protect our vital sea lanes, and powerful counteroffensives are in the making which will eventually win the day. Logistics, or the art and science of military supply, constitutes 70 per cent of victory, and more wars have been lost on account of faulty logistics than mistaken strategy or tactics.

AIR-BORNE TROOPS

Although only a small proportion of the total men and munitions were brought to the fighting fronts by air, the important thing to remember is that speed was of the essence, and saving those particular situations saved the whole show. The best examples of this are the urgently required parts flown to Egypt in the nick of time to help stop Rommel just short of Alexandria, and the fact that all men, supplies, and equipment were flown in to enable our forces to prevent the Japs taking Guadalcanal and Port Moresby and to clear them out of eastern New Guinea altogether. The air-borne troops flown some 1500 miles and landing in North Africa at just the right minute was another outstanding case. In these operations the Air Force Troop Carrier Command has been doing its stuff, and similar successes by the enemy in the case of Norway and of Crete are not even in the same league. This is not to minimize the important part played by air transport in the German campaigns, the thousands of work-horse Ju-52's constituting a vital cog in the Nazi war machine. Without them the Afrika Korps would not have been able to stage a comeback in the late spring of 1942, nor would some of the practically cut-off advanced positions on the Russian front in 1941–1942 have been able to hold out.

A WINNING COMBINATION OF PLANES?

A more widely discussed problem of air warfare is that hardy perennial, how good are our airplanes? Is the Flying Fortress as good as the Lancaster? The Warhawk as the Spitfire? The Lightning as the Focke-Wulf? Or the Airacobra as the Zero? The simple but fundamental truth is just beginning to be understood: There is no "best" airplane. An airplane can do best what it is designed to do, and a compromise of conflicting qualities is always necessary. An airplane is not to be finally judged until it has been proved in combat against the best the enemy can throw up against it. It usually takes from three to five years from the first design to such final proof, therefore in the nature of the case military leaders have to go out on a limb. The most intelligent "guesses" will win out.

Let's have a look at some of these guesses and see how they turned out. Air power may be used independently, largely following Douhet, or it may be used as a battle weapon, in close co-operation with ground forces, following the classic tradition of Clausewitz. As a matter of fact, of course, we need both "pure" air power and "co-ordinated" air power for full victory. The dreaded *Luftwaffe* was as a matter of fact almost wholly set up as a short-range army co-operation machine. Its chief weapons were the Ju-87 *Stuka;* the Me-109 short-range single-seater fighter; the Me-110 twin-engine long-range fighter and light bomber; Dornier and Heinkel medium bombers, fast, but lightly armed; and as we have seen, the Ju-52 trimotored transport. These were all in mass production in dozens of scattered plants by 1938. The entire setup was geared to work with the army, including the fast moving panzer divisions. Against nations ill-prepared in the air it worked like a charm, but there were other "guesses" in the picture.

BRITISH PLANNING

One of them goes back as far as even Hitler's early schemes. In 1934 the British Air Ministry issued a specification for a speedy, fast-climbing, short-range interceptor-fighter to carry eight .303-caliber machine guns. Two excellent designs were chosen above the others, Vickers-Supermarine winning the contract for the interceptor, which was called the Spitfire, and Hawker that for the fighter, which became the Hurricane. These first-class fighters, and the Defiant (equipped with another shrewd "guess," the power-operated gun turret for firing in every direction) saved the day over Dunkirk and during the battle of Britain. *Stukas* were shot down like clay pigeons and within three weeks were withdrawn from the conflict, the same thing happening over Smolensk a year later and Stalingrad two years later when up against the first-class Russian fighters, the MIG-3 and YAK-1. Ignoring the Nazi escorting fighters, the Spits and Hurricanes went after the bombers and knocked them down by the score. Goering and Udet had turned down the idea of the well-armed and armored long-range heavy bomber, and this wrong "guess" plus Sir Hugh Dowding's correct guess and bulldog insistence on 8 guns for the British fighters may prove one of the turning points of history.

Air Chief Marshal Sir Charles Portal, on the other hand, with a truer instinct for strategic air power, followed to some extent the insistence of American air officers that the long-range heavy bomber is the keystone of air power, and in 1936 (some time after our Boeing B-17 had started on its brilliant career in August, 1934) designs went into the works for three heavy bombers. These were the four-engine Short Stirling and Handley Page Halifax and two-engine Avro Manchester, all of which came into operation under Bomber Command in 1941 after the worst of the Nazi raids on England were over and the tempo of raids over Germany was beginning to be stepped up. The Manchester was succeeded in 1942 by the Lancaster, probably the best heavy night bomber in the world today. The Germans have their Heinkel 177 and Focke-Wulf 200-K heavy bombers, and others coming along, but it is doubtful if they will ever catch up with the parade.

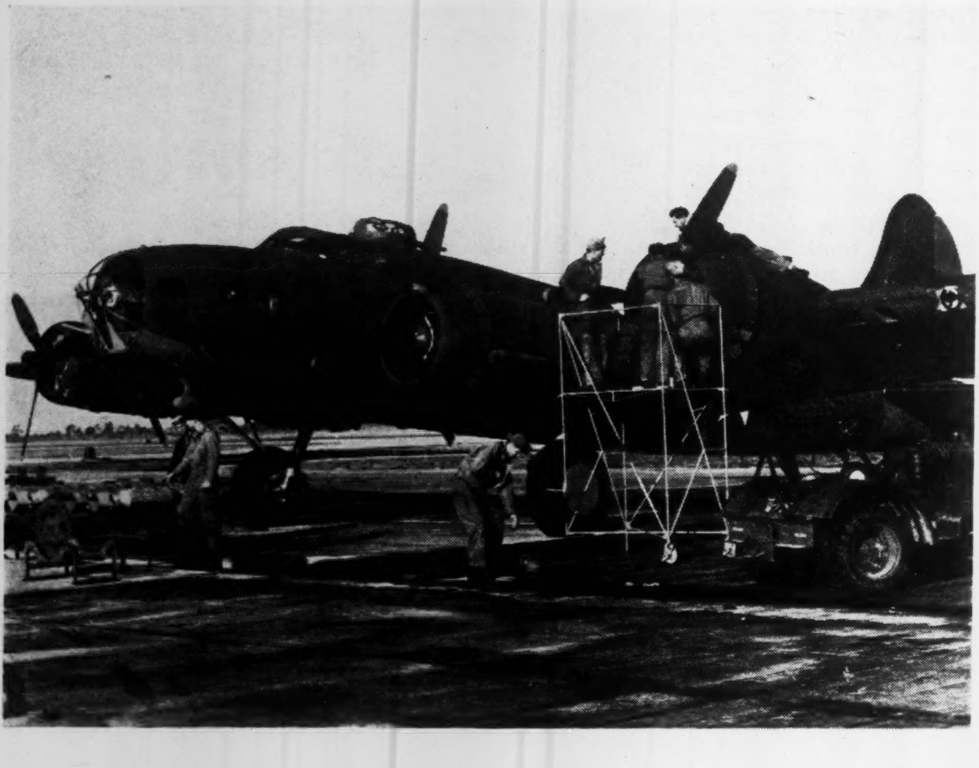
Official Photo, U. S. Army Air Force

GENERAL ARNOLD PRESENTING DISTINGUISHED SERVICE MEDAL TO MAJOR GENERAL OLIVER P. ECHOLS, COMMANDING GENERAL OF THE ARMY AIR FORCE MATERIEL COMMAND

AMERICA'S AIR PROBLEM

How about some American guesses? Maj. Gen. Oliver P. Echols, assistant chief of the Air Staff for Matériel, has stayed closer to this problem of the quality of American warplanes during the past few years than anyone else. A few months ago in an address to a large group of engineers at M.I.T. he stated: "One of the greatest military advantages of the aggressor nations is that they plan their aggression years in advance. . . . They choose the time and the place of the fight. In designing their aircraft the Germans, and also the Japanese, knew their problems. . . We did not know when the next war was coming or where our airplanes were to be used. We planned a balanced air force, based on tactical and strategic principles. Our object was to build air power which could be used and applied anywhere in the world and under greatly varied conditions. These airplanes had to be ready for production at the beginning of the war, or else it would be too late." Incidentally, General Echols was awarded the Distinguished Service Medal for his valuable contribution to America's air strength by providing the superior airplanes now in world-wide service.

Our Air Force was thus planned as a balanced team and designed for use as such. We outguessed the Axis by foreseeing



GROUND CREWS PLAY IMPORTANT ROLE IN LIFE OF FLYING FORTRESS

(*Official Photo, U. S. Army Air Force.*)

the global character of the war and providing accordingly. Under the Air Corps expansion program of 1939 for airplanes, flying personnel, ground technicians, and bases, the following nine types were set for production: In the fighter class (1) Curtiss P-40 and Bell P-39 Airacobra for ground troop co-operation and medium-altitude combat; (2) Lockheed Lightning P-38 fast-climbing, high-altitude, twin-engine interceptor and long-range fighter, and Republic P-43 high-altitude fighter, which was developed into the P-47 Thunderbolt, with 2000-hp, radial, air-cooled engine. The bombers were in three classes (1) Douglas A-20 Havoc for fast low flying sweeps; (2) North American B-25 Mitchell and Martin B-26 Marauder, powerful, high-speed 2-engine bombers for destruction of objectives at medium range, with or without fighter protection; and (3) Boeing B-17 Flying Fortress and Consolidated B-24 Liberator, long-range heavy bombers, backbone of American air power. (In most cases the names were given later.)

How well did these types fit into the pattern? Naturally some turned out better than others, but bearing in mind their designed purpose, all were good. This is the explicit testimony of Maj. Gen. Claire Chennault, commander of the 14th Air Force in China, who had nothing to do with their design but much to do with their tactical use. He has stated, "The record of American aircraft is generally that of having completed the tasks for which they were designed." Under the stress of combat conditions some of them stepped out of their league and did an unusually good job in other ways too. Take the Lightning. This ship, designed as a high-altitude interceptor, has proved invaluable as a fast reconnaissance plane, taking photographs of enemy objectives hundreds of miles away, often from heights of 25,000 feet or more. Its concentrated fire power in the nose, consisting of cannon and heavy-caliber machine guns, with its speed and ability to carry light bombs, has made it a powerful slugger for ground strafing operations. Or the Douglas Havoc, a sweet airplane to fly and a general favorite on a dozen fronts. This attack bomber has been used as a level bomber, day fighter, and night fighter. Without bomb load and with heavy concentration of guns its speed and fire power make it a dangerous customer.

The long range built into the Fortress and Liberator has saved the day in the Pacific over and over again. The same is true of our fighters, which have a far greater range than those of other countries. Or take the matter of adaptability. The Italian planes have fought only in the Mediterranean area, the Germans in Europe and Africa, and the Japs in China and the Pacific. American planes are fighting in Alaska and Iceland, Tunisia and New Guinea, over China, Russia, and Germany. Here is where our modification centers come in, where special last-minute adaptations for climate, etc., are made. During the past six months, these centers, scattered about the country, have risen to a first-rate importance in our continuing drive for top-notch quality in fighting aircraft. If one word had to be used in hitting off a description of American military planes, both Army and Navy, it would be "rugged." All classes and types have repeatedly proved their ability to take as well as give terrific punishment. The Navy too had its team of specialized types ready before the shooting started, such as patrol bombers, dive and torpedo bombers, carrier-based fighters, and scout observation planes, and improved models have come into action from time to time.

THE TEAMS IMPROVE

Besides the mistake of being too ground-minded in their tactical conception of air power, the Nazis made the further mistake of freezing their designs to get an overwhelming quantity of planes quickly. They learned both of these lessons the hard way during the battle of Britain. More recently they have been coming through with improvements on their standard models more rapidly. They used the Me-109E for over two years, the Me-109F coming along in mid-1941. Less than a year later the high-altitude Me-109G was in action, and by late winter (January, 1943) the Me-109G-2 with 1500-hp Daimler-Benz engine with two-stage supercharger, ceiling of better than 40,000 feet, and speed of 380 mph, was in service, described by a qualified observer as one of the hottest things in the air over Tunisia. The Ju-87 *Stuka* is out, its place taken by the twin-engine Ju-88 level and dive bomber, also used as an effective night fighter. An improved Ju-288 with powerful radial engines is in the works. The twin-engine Me-110 long-distance fighter and light bomber, the most formidable ship in the air during 1940–1941, is giving way to the new Me-210, faster, more wickedly armed, and very heavily armored, with over 900 pounds of armor so as to stand up to our Fortresses and Liberators. Much larger transports are coming into use such as the Ju-290 and a big six-engine plane, the Me-323. A new member of the team replacing the Heinkel 113 is the Focke-Wulf 190 fighter with radial engine, a first-class job between the 15,000- and 25,000-foot levels.

We have already noted how England has replaced her two-engine bombers such as the Hampden, Wellington, and Whitley with huge four-engine planes carrying two or three times the load. A 300-400-plane raid will now do as much or more damage than the 1000-plane raids on Essen and Cologne last June, with a far easier "traffic problem." The Spitfire I passed through the Mark V to the present Mark IX, with heavier armament and much higher speed and ceiling, owing to the two-stage supercharged Merlin 61 engine and four-bladed "airscrew." As a short-ranged interceptor, it is more than a match for Germany's best. The versatile Hurricane has also been improved, an extremely useful version carrying light bombs and known as the Hurribomber. Another effective version carries an antitank cannon; still another is the "catafighter," catapulted from merchant ships to destroy enemy bombers. A new member of the British fighter team is the fast heavily armed Typhoon, test-flown in 1940 and in service since last summer, powered by the H-shaped 24-cylinder Napier Sabre engine. Another newcomer is the remarkable all-wood Mosquito reconnaissance bomber, with a heavily armed, low-flying, long-range fighter version.

The American team went into action last of all and had the advantage of some of the air war lessons built in, such as self-sealing fuel tanks, power-operated turrets, heavy fire power, and long range. The earliest fighter, the P-40, went through several improvements, and the Airacobra is now in production in a new model using the more powerful Allison engine with two-stage supercharger. General Arnold described this as a "vastly improved airplane." A new member of the team, the North American Mustang, was originally ordered by the British and used by them with great enthusiasm. A dive-bomberattack-plane version known as the A-36 is in service with American Air Forces, fastest and best defended light dive bomber now in action. A new fighter model of the Mustang is coming along and has been hailed by some British and American authorities as likely to be the "best" fighter in 1943. Let's wait and see what the other entries are. Our bombers, too, have been improved as they go along, the 1943 versions of the B-17F Fortress and the B-24 Liberator, with their bomb capacity up to 10 tons for short runs, being far superior to the 1941 models. New and bigger bombers are on the way, but we'll talk about them when we get them.

ALLIED TYPES COMPLEMENTARY

An important factor in the United Nations' combined air strength is the fortunate manner in which British and American types in particular complement each other. We have already referred to the fact that the Spitfire is probably the best short-range high-altitude fighter in the air today. For low-altitude work with troops and tree-top-level sweeps for shooting up locomotives, goods trains, small bridges, supply dumps, and the like, the North American Mustang and Douglas Havoc (RAF Boston) fill out the picture. For long-range work at high or low level the Lockheed Lightning has emerged as one of the outstanding planes of the war, with air generals shouting for more of them from all quarters of the globe. The British have been so well pleased with American medium bombers, North American Mitchells, Martin Baltimores and Marauders, Lockheed Hudsons, and Lockheed-Vega Venturas that they have become standard, and their own models have become available for other theaters. British heavy night bombers are unexcelled for their job (page Essen, Cologne, and Dusseldorf), while the Fortresses and Liberators, with their trained crews for daylight operations, complete the round-the-clock pattern.

In the light of recent discussion one or two things need to be said on this last point. (1) American heavy bombers can bomb Germany by daylight, because it is being done. Between January 27 and March 22 there have been three heavy raids on Wilhelmshaven, and one each on Emden, Hamm, and Bremen, most of them unescorted by fighter planes, all of them with successful results, and in all cases with losses about the average of the British night-bombing operations. In daylight precise targets can be seen and hit, and that is what counts, not the number of tons of bombs dropped. (2) Leading British air officers agree with General Andrews and General Eaker

DOUGLAS A-20 HAVOCS IN FORMATION

(Official Photo, U. S. Army Air Force.)

that the round-the-clock bombing is feasible and desirable, that it will keep Nazi defenses—antiaircraft and fighter squadrons—on a three-shift basis and thinned out. But (3) to be really effective their scale must be greatly stepped up. This means more Fortresses and Liberators to Eaker, *and* equally justifiably to Chennault in China, *and* to Kenney in Australia. This brings us smack up against another problem of global air war going on all over the place, all at once—*numbers* of planes (so far we have mainly touched on quality, not quantity).

HEAVY-BOMBER PROGRAM

With the rapid overrunning of the Low Countries and imminent collapse of French resistance in May, 1940, you will recall the President's startling demand for 50,000 airplanes and an annual productive capacity of that amount. Leading experts said it would take at least three years to reach that figure. Our over-all air strength was then some 4000 planes, about the same as that of Germany in 1936. With an all-out war effort and all the materials they needed, it took them four years to reach a total of 30,000 planes and annual production of that figure; they passed this peak some time ago and will probably not recover it again. It is nothing short of a first class industrial miracle that in *two and a half years* we could turn out bombers, fighters, transports, and trainers, with their necessary engines, propellers, instruments, and spare parts on a scale of more than double the German figure, or 66,000 planes per year.

From less than 600 military planes in June, 1940, to 5500 in December, 1942—an 800 per cent increase in 30 months! This figure has not advanced much since December. January was about 5000, February was back to 5500, March close to 6000, and April should be up a few hundred more, approaching a rate of 75,000 per year. Compared with the over-all 9 per cent increase over January, the February increase in heavy bombers was 36 per cent over January and 20 per cent over December, which means that Ford, Consolidated (Texas), Douglas (Oklahoma) are coming along with their B-24's, and Douglas and Vega with their B-17's. New plants completed within the past few months, now fairly well tooled up, should boost total airplane production within the near future, as indeed it will have to if the country is to anywhere near reach the projected goal of 100,000 planes in 1943. The scale of annual deliveries has been running as follows: 1940, 6000 planes; 1941, nearly 20,000; 1942, nearly 49,000, with almost three times the total *weight* of the 1941 deliveries, which is really what counts. Numbers of units mean very little. A training plane may weigh 2000 lb and a four-engine bomber 50,000 lb, but both count as an "airplane." The 1943 goal of 100,000 has been estimated to triple the weight of the 49,000 planes delivered in 1942, indicating a still higher proportion of the urgently required four-engine heavy bombers and large cargo-transport planes. Our guess is that if the industry can turn out 90,000 planes, not counting gliders, it will be doing a right smart job. I mean a total of 90,000 delivered, not a production rate of 90,000, which we ought to attain by the middle of the year.

Coming to heavy-bomber-production development it may be recalled that during the summer of 1940 one of the big questions was the breakdown of the 50,000 planes. What types of airplanes did we really need? Early in the fall contracts were let for some 500 each of the Boeing B-17 and the new Consolidated B-24, 2 per cent of the proposed 50,000. This was the start of the heavy-bomber program, soon to be augmented by the Knudsen plan of new southwest plants for Consolidated and Douglas for assembling parts and subassemblies of B-24's to be turned out in a large bomber factory to be built by Ford near Detroit. It was about this time that Mr. Robert A. Lovett, an investment banker and World War flier was brought into the Secretary of War's office as a special assistant for aircraft production and related matters. His appointment as Assistant Secretary of War for Air in April, 1941, coincided with the return of General Arnold from a trip to England, shortly after which the President announced that the heavy-bomber program would be increased to a total of 500 per month. In planning at least, the heavy bomber was beginning to emerge as the war's primary offensive weapon, a view long held by our air leaders, including Generals Arnold, Andrews, Spaatz, Echols, Emmons, Kenney, Olds, and many others and abundantly vindicated during the past year of fighting.

To meet the new program it was agreed that Consolidated and Douglas would do some manufacturing as well as assembling, and Ford's plant at Willow Run was projected on a vastly greater scale to turn out many more subassemblies than originally planned and also, after considerable discussion, finished planes as well, necessitating adding a large airfield to the project. In the meantime Boeing's greatly improved B-17E model had been accepted and plans went into high gear to turn this out in quantity as a still further improved B-17F at the main plant in Seattle, with parts and subassemblies from the Wichita factory, and at the new Douglas and Vega plants in southern California.

After Pearl Harbor, with the envisioned need of hundreds more of these big bombers for the long-ranged Pacific warfare, Donald Nelson announced that the heavy-bomber program would be doubled again. No new plants were needed for the Flying Fortress pool, but North American was brought into the picture to build Liberators at a new factory in Texas to be completed early in 1943. In getting all this stuff rolling tens of thousands of hours were saved in preliminary work by pooling the engineering staffs, blueprints, tooling setup, and the like, and in the process of approaching something like mass production, with completely interchangeable parts to facilitate servicing at the fronts, assembly-line techniques, highly intricate machine tools, and also hitherto untried processes have been developed, all resulting in the amazing shrinkage of man-hours from over 100,000 per 4-engine bomber to around 30,000. The situation was complicated by the sudden demand for a large number of heavy cargo-transport planes to keep our global life lines going, and an excellent temporary solution was hit on by converting the B-24 Liberator bomber into the C-87 Liberator Express. At Consolidated's Texas plant (actually *a longer* factory than Willow Run) and at Ford's, both of these types are being turned out together. It begins to look as though Andrews and Spaatz, Kenney and Chennault will get their big bombers after all. They need them by the hundreds, not by the dozens, and when they get them in such quantity we may begin to find our answer as to what air power can do to help win the war.

HORSEPOWER FOR VICTORY

How about engines for all these planes? At the Aviation Forum in Washington at the end of May, 1940, Col. Jack Jouett, then president of the Aeronautical Chamber of Commerce, told me that high-powered engines for combat aircraft (1000 hp or better) would probably be a bottleneck in the program for at least 18 months. Allison had at that time hardly got going, and for air-cooled radials Wright Aeronautical and Pratt & Whitney were just beginning their plant expansions. (Earlier British and French orders for engines and propellers and a few types of planes had helped this plant-expansion picture). However, by superhuman efforts (some of you may know something about how it was done) another rabbit was pulled out of the hat, and the situation was never serious except for a few weeks when Curtiss P-40 "gliders" were waiting for Allison engines, and Boeing B-17's were flown away from the factory to heavy-bombardment bases, engines removed and flown back to Seattle by Air Corps cargo transports to fly the next Fortress away. Wright's huge new plants near Cincinnati and at Paterson, and Pratt & Whitney's expanded plant at Hartford, various satellite factories for parts, and a new plant at Kansas City helped a lot, and wholesale conversion of

British Information Services

R.A.F.'S IMPROVED SPITFIRE IX WITH TWO-STAGE SUPERCHARGED MERLIN 61 ENGINE AND 4-BLADED PROPELLER FOR STEPPED-UP PERFORMANCE AT HIGH ALTITUDE

the automotive and other industries has also been a major factor. Ford came through months ahead of schedule in getting quantity production on Pratt & Whitney 2000-hp Double Wasps for the Thunderbolt and Commando, and Nash is now turning out similar engines for Navy's powerful Corsair fighter. Buick is ahead of schedule on a huge number of 1200-hp Pratt & Whitney Twin Wasps for the Liberator and Liberator Express, and Chevrolet has also begun production of this engine. Studebaker is producing Wright Double Cyclones (1700 hp) and by summer a huge factory near Chicago should be turning out the big 18-cylinder Wright R-3350 Duplex Cyclones (2000 hp plus), which power the Lockheed Constellation high-speed transport, and which will be used on other new models coming along in 1943. Yes, it looks like plenty of engines on the horizon, and when Hitler tied his war to the gasoline engine he ran it right down our alley. Millions of horsepower per month for victory.

GLOBAL AIR SERVICE

All these engines kicking around brings up another first-class headache—the task of overhauling and servicing to keep our planes flying. In many ways this is the most difficult problem of all, and one in which, despite the solid achievements and countless miracles of improvisation during the past 15 months, there is still a great deal to do. The Air Service Command, charged with the vital responsibility of providing supply and maintenance facilities to Army Air Force tactical squadrons in every part of America and the world, thus has one of the most difficult and exacting assignments of the entire war effort. Organized in the autumn of 1941, in less than a year and a half the ASC has grown to be the largest command in the Army Air Forces, with more than a quarter of a million officers, enlisted men, and civilian personnel, including tens of thousands of women.

The commanding general is Maj. Gen. Walter H. Frank, who organized the tremendous maintenance setup for the 8th Air Force in England. On the basis of his experience overseas, some months ago he recommended a reorganization intended to increase the speed and efficiency with which the Air Service Command can supply and maintain Army Air Force planes for combat service throughout the world. He has said, "Our planes and engines must be maintained on every front the world over. Unless we do that job and do it effectively, we shall prolong this war." The United States has been divided into 11 Air Depot Control Area commands, and the Overseas Division is organized into various "wings," such as the Middle East Wing, which are now being strengthened as rapidly as possible with the necessary personnel, shops, depots, and other facilities to keep every bomber, fighter, and transport in flying condition until unchallenged air supremacy is secured and the way opened up for final victory.

As an important part of the general streamlining and realignment of functions of the Army Air Forces as a whole, effected about the end of March, Maj. Gen. Oliver P. Echols, Commanding General of the Matériel Command, was made an assistant chief of the Air Staff in charge of matériel, maintenance, and distribution. It thus became his responsibility to see that all activities of the Matériel Command, Air Service Command, and Air Transport Command were properly coordinated and kept humming. These interrelated functions, now so vast in their scope, were nursed along by General Echols (then a Colonel) a few years ago at the Air Corps Matériel Division, Wright Field.

There are really four prime necessities in successful military-aircraft maintenance: (1) Maintenance bases and equipment; (2) parts and supply distribution; (3) trained personnel; and (4) transport.

1 Maintenance bases fall into two classes (1) squadron and base engineering groups providing the smaller type of repairs and overhaul, known as 1st and 2nd echelon maintenance; and (2) the mobile service squadrons and large permanent supply depots well behind the lines, providing 3rd and 4th echelon maintenance. General Chennault laid down a very practical rule for his Flying Tigers and has carried it over into his 14th Air Force operations. "The AVG is a tactical fighting unit. As such we cannot possibly run a maintenance unit other than simple ground operations on the field, not to exceed 15 minutes in duration. If a plane cannot be prepared for flight within that quarter-hour, it should be withdrawn to a dispersal point for servicing by maintenance personnel." Here we see the distinction between the 1st or 2d echelon maintenance on the field with hand tools, and the 3rd echelon maintenance at the base, with heavier but mobile tools and machinery. The 4th echelon maintenance consists of major overhauls, rebuilding jobs, etc., carried on at a main depot, such as the recently completed huge supply, repair, and maintenance Air Base "somewhere in North India."

As part of their service setup in the world-wide distribution and operation of their products, the aircraft and engine manufacturers and instrument companies are providing invaluable assistance at these bases. Lockheed has a huge establishment in England, for example, Douglas in Africa, with Curtiss, Bell, Boeing, Consolidated, Martin, and the others in the picture; Allison, Wright, and United Aircraft for engines and propellers, and Sperry, Bendix, and others for instruments. At these big bases behind the lines all types of aircraft and engines actively in service in the area can be taken care of. The trained trouble shooters from these companies not only help keep things rolling at the front, but they also act as expert observers to keep the home front informed as to better methods and vital changes. In actual combat conditions structural failures and other "bugs" frequently develop which are not brought to light in even the most drastic tests.

2 At the moment the parts and supply distribution is one of our most serious problems. Consider the distances involved; the vast number of parts for planes, props, engines, and gadgets; the various types of planes; the changes in models; the lack of local tools and facilities on many of our fighting fronts, and some idea will be gained of the staggering job to be done. While in command of the Middle East, General Andrews is reported to have said that he wished the aircraft companies would quit making planes for a month and devote all their time to turning out parts so as to keep the planes we did have at the front in service. It is understood that the manufacturers are on the average 70 to 80 per cent up to schedule on their parts contracts and it is now largely a matter of distribution. Another Air Corps general has been quoted as saying, "Spare parts will win the war." That may be an oversimplification on the part of a commander on the spot itching to do a more effective job but hindered on account of an exasperating lack of a very minor but indispensable part, but there is a very real truth behind it. At the present time, with every airplane shipped or flown to the front, several months' supply of spare parts is included. In the case of engines, complete extra engines as well as parts are sent, more per plane to a dusty theater like North Africa where engines wear out faster.

A recent story from the North African front is worth repeating. One day 14 of our planes were damaged, some slightly, others severely. Every single plane counts—plenty, and it is the job of the repair section to get these planes back into the air just a little faster than is humanly possible. The squadron engineers took almost a whole morning to survey in a jeep the entire situation, estimate the damage, plan the program, and then get rolling. By that evening five of the planes were ready for action and three more the next day, with four more the day following. The other two had been turned into salvage for spare parts—"cannibalizing" they call it, and that means two less planes for combat because of a lack of spare parts, a situation which has been in effect on practically all fronts since the start of the war, but now improving. Anyway, the point is that it would have taken a couple of months in peacetime, in well-equipped shops at home, to have gotten those 12 planes fit to fly again. These impossibilities are being done every day on our advanced fronts.

3 The huge job of training the hundreds of thousands of lads to do the servicing is the responsibility of the Technical Training Command, whose motto is "Alas susteneo"—I keep the wings up. From scores of schools, including dozens of the biggest hotels in Miami Beach, Atlantic City, Chicago, Detroit, and elsewhere, tens of thousands of trained aircraft and engine mechanics, radio operators and technicians, armorers, welders, sheet-metal workers, and dozens of other specialists are rolling out every few weeks. Some of these go on to the various aircraft and engine factories and take short courses right on the spot to learn the ins and outs of the stuff they will have to service at the front. Periodical "maintenance maneuvers" are held, during which the boys work on damaged planes under simulated battle conditions, and with a minimum of tools and light equipment "get 'em flying" in the shortest possible time.

4 We have already covered air transport as a pace-setting function in modern warfare. For more than a decade this has been an important element in American Army aviation, with the slogan, "All Air Corps supplies by air." The latest development is the huge air freight and fast express service, the newly activated 39th Air Freight Wing of the Air Service Command. This outfit speeds the delivery of aviation equipment and supplies for all arms and services to the various fighting fronts. Modern warfare is fast moving, not static, and keeping a constant flow of parts and supplies coming along by air to the places they are urgently needed is one of the most important jobs of all.

We have seen how the Army Air Forces within a few months of our entrance into the war was battling the enemy over practically every continent and every ocean; the airplanes they had with which to do the job, how they compared with those of other countries and how they have been constantly improved; how America has been winning the battle of quantity as well as quality; and the problems that are now in the process of solution whereby our planes can be kept flying until victory is assured.

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FOOTNOTE ON COMPARATIVE PLANE PERFORMANCE

As we have indicated, an absolute comparison of one airplane with another, without regard for its designed purpose and particular combination of qualities (and compromises) the designer had in mind, is unfair. The box score of battle results is on the whole a good indication of the quality of military airplanes, but that, too, may be affected by the skill or even the philosophy of the pilots, and the combat conditions. On the basis of the box score the American record, both Army and Navy, for 1942, showed an average in each service of about four enemy planes shot down to one of ours lost. This is a better showing than any other air force in the war to date.

Another yardstick which appears to be more theoretical but actually may be more accurate for an absolute comparison, plane for plane, is a "combat efficiency" rating based on factors in the performance of military aircraft, properly weighted as between fighters and bombers. For example, in a fighter, climb and maneuverability will rate higher than in a bomber, whereas range will be lower. Some of the performance factors are: speed, climb, ceiling, firepower, armor, maneuverability, bomb load, defense, range, ease of production and maintenance.

The following is an unofficial list of suggested types common to any land-based air force, with some of the best entries as of April 1, 1943, actually proved in combat.

Class	United Nations	Axis[a]
Heavy day bomber	Fortress, Liberator	Focke-Wulf 200 K
Heavy night bomber	Lancaster	Heinkel 177
Medium day bomber	Marauder, Mitchell	Dornier 217 E-2
High-speed fighter-bomber	Mosquito, Havoc (A-20) YAK-4	Messerschmitt 210 A-2
Long-range night fighter	Beaufighter, Havoc	Junkers 88 B
Reconnaissance scout	Mustang I	Messerschmitt 109F
High-altitude fighter	Lightning (long range) Spitfire IX (short range)	Messerschmitt 109 G-2
Anti-bomber fighter	Typhoon, YAK-1	Messerschmitt 210
All-purpose fighter (low and medium level)	Warhawk, Hurricane, MIG-3	Focke-Wulf 190/290
Anti-tank and ground strafer	Airacobra, IL-2 (Stormovik)	Henschel 129
Troop transport	Commando, Skytrooper	Junkers 52
Cargo transport	Liberator Express	Junkers 290

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[a] Only German types are listed. At the moment no Italian or Japanese models appear to qualify except the Mitsubishi navy Zero, or S-00. This is a light but fragile all-altitude fighter. The box score of 4 to 1 over these planes last fall is now around 6 to 1 with Navy Wildcats and Corsairs, and Army Lightnings, Airacobras, and Warhawks. It is even better if those shot down by our bombers are included. The newest Jap fighters appear to be good but have not been tried long enough nor in sufficient quantities to appraise their worth. They are also turning up with their own models of the older Me-109 and twin-engine Me-110, according to reports. 1940–1941 Italian fighters such as the Macchi 202 are now being equipped with German Daimler-Benz engines to step up their performance.

Performance Characteristics of a
DOWNDRAFT COKING FURNACE

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According to "Coal Resources of the World," compiled on the initiative of the Executive Committee for the Twelfth International Geological Congress, the total coal resources of the United States are distributed among the different types approximately as follows:

Anthracite and semianthracite	$^2/_3$ of one per cent
Semibituminous	$1^1/_3$ per cent
Bituminous	41 per cent
Subbituminous	27 per cent
Lignite	30 per cent

Bituminous coal, subbituminous coal, and lignite constitute approximately 98 per cent of our total solid-fuel reserve, and the fact that practically every hand-fired furnace, boiler, stove, and water heater now in use is incapable of burning any of them efficiently or smokelessly stands as a challenge to every combustion engineer and furnace designer in the nation.

If efficient and smokeless combustion is to be achieved in a hand-fired furnace burning a high-volatile fuel, the design of the furnace must include provision for the complete combustion of all of the hydrocarbon gases which make up that portion of the fuel which is known as volatile matter. The requirements for complete combustion of the volatile matter found in high-volatile fuels may be simply stated as follows:

1 The rate at which the volatile matter is converted to a gaseous state must be controlled.

2 Sufficient secondary or overfire air for the complete combustion of the hydrocarbon gases contained in the volatile matter must be supplied at all times.

3 Secondary air must be thoroughly mixed with the gases.

4 The mixture of gas and air must be heated to a temperature which will insure its ignition. Experiments by J. W. McDavid[1] have indicated that when coal gas-air mixtures are heated by the sudden application of a hot body, a temperature of at least 1500 F is required to insure their instantaneous ignition.

Conventional updraft furnaces of all types are provided with a grate, a fire pot, and a combustion chamber, arranged one above the other in the order named. The only convenient method of adding fresh fuel is to pile it on top of the hot coals. When the fresh fuel is placed on top of the coals, it comes between them and the heating surface of the furnace with the result that the heat output of the furnace is temporarily decreased. Since a relatively low temperature is required to convert the volatile matter in the coal to the gaseous state the gases contained in each charge of fresh coal are liberated very rapidly. It has been found impracticable to supply sufficient secondary air to completely burn the gases from a new charge of coal during the period that follows the firing of the furnace, and as a result a large portion of the gases usually passes out of the chimney unburned. Even if provision were made for the introduction of sufficient secondary air in the coking period at the beginning of the cycle, much of the gas would still be wasted because of no provision for ignition of the gas-air mixture.

Various "so-called" scientific methods of hand firing "soft" coal, such as the coking method, the alternate method, the pyramid method, and the "nut and slack" method, have been suggested for circumventing the fact that conventional equipment is not designed to burn high-volatile fuel. Tests made in the mechanical-engineering laboratory at the University of Illinois have indicated that the "nut and slack" method is far more effective for reducing smoke than any other scientific method.

One objective of the scientific methods of hand firing "soft" coal is to coke slowly a charge of fresh fuel on one half of the grate while the coke from a previous charge is burned on the other half. However, unless all of the hot coals are moved from that part of the fire pot which is to receive the charge of fresh coal, those remaining will defeat this objective by coking the fuel too rapidly. A second objective is to leave at least a part of the surface of the hot coals exposed, so that the radiant heat from the exposed portion may ignite the mixture of hydrocarbon gases and air in the combustion space above the fuel bed. But if too much ash has accumulated under the bank of hot coals, the resulting low combustion rate will not produce a surface temperature that is hot enough to accomplish the ignition of the gas-air mixture.

In many large cities where the smoke from thousands of hand-fired plants has become almost unbearable, intensive and sustained efforts have been made to teach the householders better firing methods; but almost without exception, these crusades for cleaner cities through better use of conventional coal-burning equipment have failed to effect a noticeable improvement.

Experience indicates that there are only three practicable ways of dealing with the smoke problem, namely, mechanization of all coal-burning equipment, large and small; processing all high-volatile fuels to remove at least a part of the volatile matter; and redesign of hand-fired furnaces, boilers, stoves, and water heaters so that "soft" coal can be burned by any householder without producing an appreciable amount of smoke. Mechanization of domestic coal-burning equipment will undoubtedly advance rapidly after the close of the present world conflict and facilities for coking some of the better grades of bituminous coal will probably be expanded, but without question the hand-fired furnace will always be used by our citizens whose incomes are in the lower brackets and there will always be a crying need for a design capable of burning the low-cost fuels smokelessly and efficiently.

NEW DESIGN

After making a thorough study of the burning characteristics of high-volatile bituminous coal, J. C. Miles and the author, members of the mechanical engineering department at the University of Illinois, have perfected and patented a design principle which we have chosen to call the downdraft coking principle. When applied in the design of a hand-fired furnace of any type, the unit produced will be capable of burning high-volatile bituminous coal both efficiently and smokelessly. Fig. 1 is a photograph of a small unit made under license by the University of Illinois Foundation. The photograph shows the unit set up in the mechanical-engineering laboratory at the

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[1] "The Temperature of Ignition of Gaseous Mixtures," by J. W. McDavid, Trans. Chemical Society (London), vol. 3, 1917, pp. 1003–1015.

Contributed by the Fuels Division and presented at the Spring Meeting, Davenport, Iowa, April 26–28, 1943, of The American Society of Mechanical Engineers.

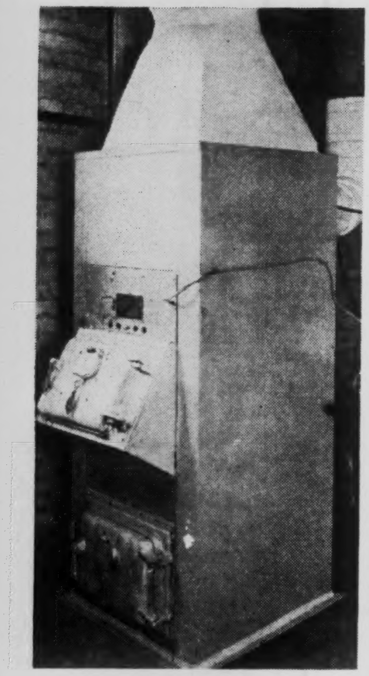

FIG. 1 DOWNDRAFT COKING FURNACE NOW UNDER TEST

University of Illinois and arranged for testing as a forced-circulation warm-air furnace. This same unit with some modifications in the casing could be used as a gravity-circulated warm-air furnace or as a circulating space heater.

Fig. 2 is a vertical longitudinal section of the furnace and shows the arrangement of the hot coals and the fresh coal, immediately after firing. The procedure used in adding fresh fuel is: (1) Shake the rocking grate at the rear of the furnace to remove a part of the accumulated ash; (2) push the hot coals from the previous charge along the sloping floor of the coking chamber onto the sloping pinhole grate; and (3) pour the fresh coal into the coking chamber from a scuttle. The only tool required is a conventional poker and the technique is as simple as pulling back the covers before getting into bed. The baffle wall at the rear edge of the coking chamber prevents covering the hot coals with the fresh coal. The baffle wall also directs the gases as they are released in the coking process over the surface of the incandescent coke. The primary undergrate air enters the ash pit through a port in the ash-removal door and passes upward through the grate and the bed of hot coals as in the conventional furnace, but the products of combustion from the coke bed do *not* pass through the fresh coal. The primary coking-chamber air enters the furnace through a port in the firing door and supports a low combustion rate in the coking chamber which liberates heat that gradually converts the volatile matter in the fresh coal to the gaseous state. The secondary air enters the furnace through ports above the firing door, is conducted through a horizontal passage over the coking chamber, and then through vertical passages in the baffle wall. The secondary air emerges from the bottom of the baffle wall to mix thoroughly with the hydrocarbon gases emanating from the coking chamber and any carbon monoxide gas from the coke bed. The gas-air mixture is ignited by the incandescent surface of the hot coke and is burned in the small refractory-lined combustion chamber back of the baffle wall. An auxiliary combustion chamber is provided in the upper portion of the furnace to insure complete combustion at higher rates of burning. From the auxiliary combustion chamber products of combustion pass through a radiator to the breeching and chimney.

It is the intention in the design of the downdraft coking furnace that all three ports would be adjusted at the factory or by the dealer for the type of fuel that would be the logical choice in the customer's locality. (One adjustment has been found to be satisfactory for all types of high-volatile bituminous coal.) The householder would neither adjust nor operate any dampers except the cross damper in the smoke pipe with which he would control the effective draft at the smoke collar. The smoke pipe or breeching should preferably be equipped with a barometric draft regulator located between the cross damper and the entrance of the smoke pipe to the chimney, to provide a constant draft for the operation of the furnace and to eliminate the possibility of the furnace overheating. The furnace can be satisfactorily controlled with a conventional check damper, but better efficiency can be achieved at low rates of burning by using a cross damper capable of reducing the effective draft at the smoke collar to an amount as low as 0.001 inch of water.

The foregoing described furnace is identical in principle with the experimental model described in a previous paper.[2] The unit shown in Figs. 1 and 2 was designed to occupy a minimum of floor space by placing a part of the combustion space above the secondary air passage instead of using one large chamber as in the original experimental model.

COMPARISON TESTS

To prove the versatility of the downdraft coking furnace, tests were made at the maximum rate of burning, at the minimum rate of burning, and under conditions simulating night banking. The results of the tests are shown in Figs. 3 to 5, inclusive. Figs. 3 to 5 also show data taken from a conventional furnace operated under conditions identical with those used in testing the downdraft coking furnace. The conventional furnace which was used in the tests was equipped with a refractory-lined fire pot, was 26 in. in diameter, and had a grate area of approximately 2 sq ft. The downdraft coking furnace was 18 in. square and had a total grate area equivalent to one sq ft of conventional grate construction. In the tests at maximum and minimum rates of burning the combustion rates were proportioned in each test to the size of the furnace used. The fuel used in the tests was Saline County, Ill., coal having the following proximate analysis: moisture 3.5 per cent, volatile matter 38.22 per cent, fixed carbon 51.61 per cent, and ash 6.67 per cent.

HIGH-RATE BURNING

The conventional hand-fired furnace is very unsatisfactory

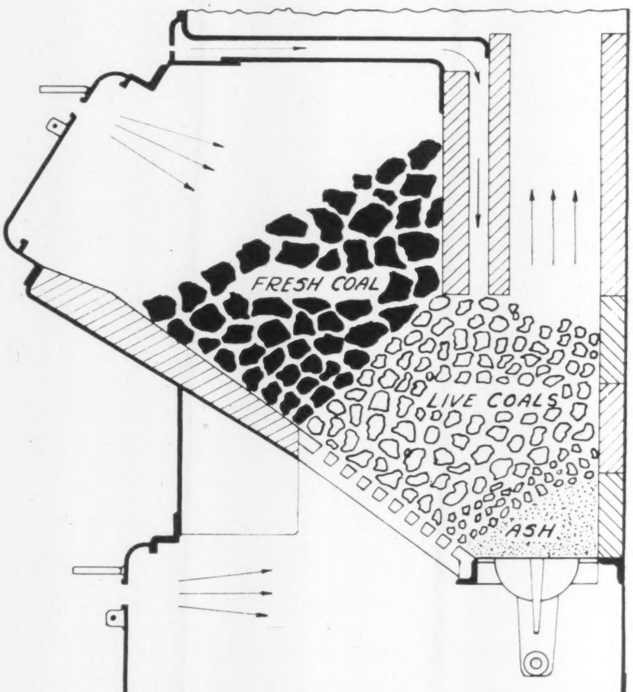

FIG. 2 LONGITUDINAL VERTICAL SECTION OF A DOWNDRAFT COKING FURNACE SHOWING CONDITION OF FUEL BED AFTER PLACING A CHARGE OF FRESH FUEL

when a high burning rate is required. When fresh fuel is added in the conventional manner the heat output of the furnace is decreased for 15 or 20 min by the blanketing effect of the charge of fresh coal. The hot coals under the fresh coal vaporize the volatile matter at a high rate and a dense smoke is emitted for a considerable period after each firing, as was the case in the two cycles shown in Fig. 3. When the fresh coal has been heated sufficiently to ignite the gas-air mixture above the fuel bed, the fire becomes extremely hot. In the test of the conventional furnace shown in Fig. 3, it was necessary to check the fire when the flue-gas temperature reached 1020 F to prevent damage to the furnace. The combustion rate decreased rapidly after the ash-pit damper was closed and the draft checked, with the result that it was necessary to turn the fire on again after a comparatively short time.

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[2] "An Improved Hand-Fired Furnace for High-Volatile Coals," by J. R. Fellows and J. C. Miles, Trans. A.S.M.E., April, 1942, pp. 161–167.

In contrast with the conventional furnace, the downdraft coking furnace responded with an accelerated rate of heat delivery the instant that a fresh charge of fuel was placed. The combustion rate quickly reached the maximum permitted by the position of the cross damper selected and remained approximately the same throughout the cycle without any attention whatsoever. The trace of smoke from the downdraft coking furnace at the beginning of the cycle, shown in Fig. 3, was caused by the necessity of leaving the firing door open a few moments while placing the charge. However, the amount of smoke produced was negligible when compared with the amount produced by the conventional furnace. In spite of the fact that the downdraft coking furnace was operated twice as long as the conventional furnace without refiring, the average CO_2 in the flue gas was considerably higher. In addition to burning the fixed carbon of the coal more efficiently, the downdraft coking furnace burned practically all of the volatile matter in the fuel, whereas it has been estimated[3] that unburned gases account for around 20 per cent of the heating value of high-volatile fuels when they are fired in the conventional manner in conventional hand-fired furnaces.

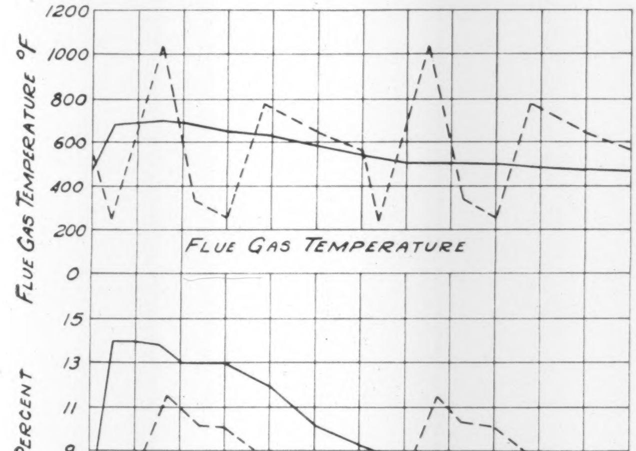

FIG. 3 GRAPHICAL LOGS OF DATA FROM DOWNDRAFT COKING FURNACE AND CONVENTIONAL FURNACE WHEN OPERATED AT A HIGH COMBUSTION RATE OF 7.5 LB PER SQ FT OF GRATE SURFACE PER HR

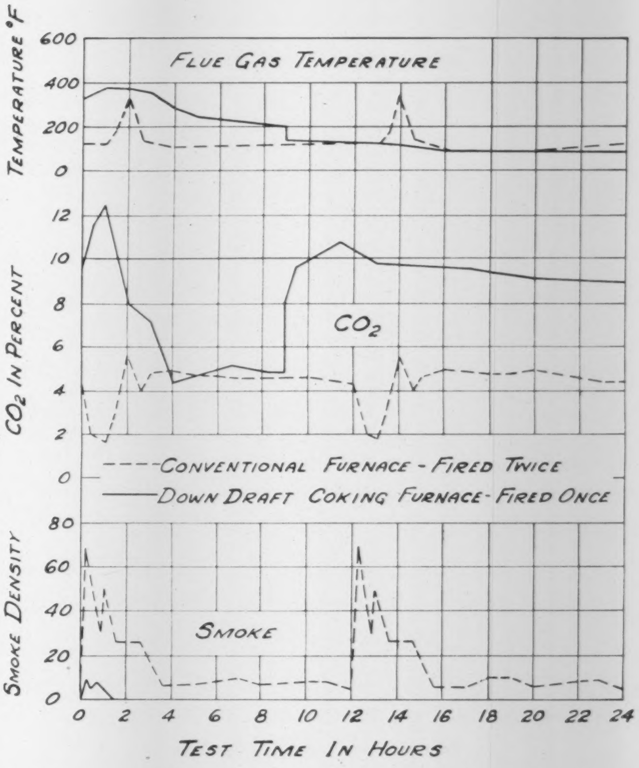

FIG. 4 GRAPHICAL LOGS OF DATA TAKEN FROM A DOWNDRAFT COKING FURNACE AND A CONVENTIONAL FURNACE WHEN OPERATED AT A LOW COMBUSTION RATE OF 1 LB PER SQ FT OF GRATE SURFACE PER HR

LOW-RATE BURNING

The conventional furnace is also very unsatisfactory when it is necessary to maintain a very low combustion rate as in the fall and again in the spring. In order to control the fire the householder maintains a comparatively deep ash layer under the fuel bed, which impedes the flow of air and causes the fire to be very slow in responding when fresh fuel is added. While the maximum smoke density is somewhat less than that from high-rate burning, the smoke usually persists for a much longer time. It is not uncommon for a charge of fresh coal to smolder throughout the entire cycle, producing a very objectionable smoke and wasting all of the volatile matter in the fuel. Much of the time in fall and spring the days are so warm that no heat is required, but the householder finds it necessary to fire the furnace in the morning, as well as in the evening, to avoid the necessity of rekindling the fire the following evening. The downdraft coking furnace will hold fire for 24 hours on one charge of fuel and although it is necessary to maintain a higher combustion rate during the fore part of a 24-hour cycle, while the gases from the volatile matter in the charge are burning, the furnace can be fired in the evening so that the higher rate of heat release will occur throughout the night when the outdoor temperatures are lowest and the demand for heat is the greatest. By changing the cross damper to the "hold fire" position in the morning on warm days, the combustion can be reduced to a very low rate throughout the remainder of the 24-hour cycle. Moving the cross damper to the "hold-fire" position after nine hours of operation at the "slow-fire" position in the test shown in Fig. 4 caused an abrupt decrease in the flue-gas temperature and an equally abrupt increase in the proportion of CO_2 in the flue gas.

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[3] "Heat Transference and Combustion Tests in a Small Domestic Boiler," by John Blizard, W. M. Myler, Jr., J. K. Seabright, and C. P. Yaoglou, Trans. A.S.H.V.E., vol. 29, 1923.

It may be noted from the flue-gas-temperature curves shown in Fig. 4 that the fire in the downdraft coking furnace responded at once when fresh fuel was added, after holding fire for 24 hours, whereas there was no response from the conventional furnace during the first hour after firing, in spite of the fact that only 12 hours had elapsed since the placing of the previous charge of fuel. Though some smoke may be produced by the downdraft coking furnace if the coke bed is allowed to burn too low before fresh fuel is added, the fire picks up with amazing rapidity when the firing door is open, and the necessary ignition temperature at the bottom of the baffle wall can be reestablished in a very few minutes by leaving the door open. The trace of smoke at the beginning of the cycle shown in Fig. 4 was caused by the comparatively low temperature at the bottom of the baffle wall resulting from 24 hours of operation on a single charge of fuel. It may be noted from the data shown in Fig. 4 that under the condition of low-rate burning the downdraft coking furnace produces a negligible amount of smoke when compared with the smoke produced by the conventional furnace at the same proportional rate of burning. The average CO_2 in the flue gases from the downdraft coking furnace was more than double the average in the flue gases from the conventional furnace in spite of the fact that the duration of the cycle was twice as long.

NIGHT BANKING

Fig. 5 shows the results of tests made with a conventional furnace and the downdraft coking furnace under conditions intended to simulate the practice of night banking in cold weather. It is the custom of the average householder to place a large charge of fresh coal in the furnace, then check the fire, just before retiring, so that he will have a good coke bed for warming up the house in the morning. Because of the low rate of heat release from the bed of coke below the fresh coal, the upper surface of the charge does not become sufficiently heated to ignite the hydrocarbon gases as they are released, and as a result, the fire pot of the conventional furnace becomes a "stew pot" which puts out a continuous stream of nauseating vapors throughout the greater part of the night. The greater portion of the volatile matter contained in the banking charge passes into the atmosphere to torment neighbors who live on the leeward side of the offending house.

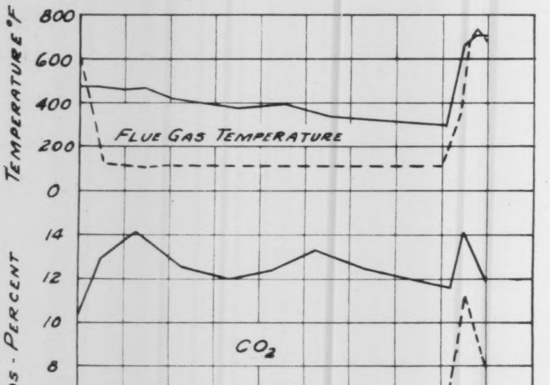

FIG. 5 GRAPHICAL LOGS OF DATA TAKEN FROM A DOWNDRAFT COKING FURNACE AND A CONVENTIONAL FURNACE WHEN OPERATED UNDER THE CONDITIONS OF NIGHT BANKING

(Each furnace was charged with 50 lb of coal, then checked or 8 hr, after which the dampers were opened.)

It was under the operating condition of night banking shown in Fig. 5 that the downdraft coking furnace showed the greatest improvement over the conventional furnace. The comparatively uniform flue-gas temperature, consistently high CO_2, and complete absence of smoke all indicate complete combustion of the volatile matter in the banking charge, whereas the low flue-gas temperature, low CO_2, and persistent smoke all indicate that the greater portion of the volatile matter in the banking charge in the conventional furnace failed to burn.

The heat released by the burning gases in the downdraft coking furnace would balance the heat losses from the house and maintain a comfortable temperature throughout the night, whereas the very low heat release from the banked fire in the conventional furnace would result in a cold house in the morning. It is impossible in any hand-fired furnace to completely stop the consumption of fuel upon retiring at night by setting the thermostat for a lower temperature, but the data shown in Fig. 5 indicate that it is possible with a downdraft coking furnace to maintain steady burning throughout the night and have sufficient pickup capacity in the morning for warming up the house by simply opening the cross damper in the breeching. Any clock-operated device that would automatically open the damper at the proper time would provide the householder with a warm house in the morning without arising early to turn on the furnace.

POSSIBILITIES OF THE DOWNDRAFT COKING FURNACE

Tests at a maximum burning rate, at a minimum burning rate, and under conditions of night banking, indicate that the downdraft coking furnace is capable of burning high-volatile bituminous coal smokelessly under all of the unfavorable operating conditions that it would be called upon to meet in heating a home throughout a heating season. In tests at intermediate rates of burning, the furnace gave smokeless combustion, good efficiency, and uniform heat release for as long as 12 hours on one charge of fuel. The furnace will operate for as long as 24 hours on one charge of fuel when the demand for heat is low.

Analyses of flue-gas samples taken for many different operating conditions indicate that high-volatile fuels can be burned in the downdraft coking furnace with good efficiency over a wide range of combustion rates. No special skill is required for the successful operation of the furnace, and no adjustment of the air-inlet ports is necessary in varying the combustion rate from a minimum to a maximum. The only means of regulation required is a simple cross damper in the breeching; the fire responds instantly to a change in the damper setting and will maintain a uniform heat output at the desired rate for any fixed damper setting. The furnace would respond perfectly to thermostatically operated dampers and there would be no danger of explosions from checking the fire after firing fresh coal.

The downdraft coking principle is applicable to all types of hand-fired heating equipment such as boilers, heating stoves, cooking stoves, and water heaters, in addition to warm-air furnaces. Experiments with a baffle wall constructed entirely of firebrick indicate that this principle can be applied to hand-fired furnaces without using any expensive alloy metal in the construction. Application of the principle to all types of hand-fired heating devices would practically eliminate smoke and soot and save many millions of tons of fuel every year.

An Engineering Discussion of the DESICCATION *of Human* BLOOD PLASMA

By DAVID C. PFEIFFER

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MOST people are aware of the Army-Navy blood-collection program sponsored by the Red Cross. More than 1,000,000 people have already donated a pint of their blood, and it is expected that several million will have contributed to the cause before this program is completed. Very few of these people have any knowledge of the procedure between the collection of the blood and its administration as plasma to some wounded soldier or sailor. Much has been written in medical journals concerning the therapeutic value of human plasma, particularly in the treatment of shock.

Blood can be kept 10 days to 2 weeks if maintained at a temperature just above freezing. Retained for longer periods, the cells rupture, making the blood unfit for normal use. Because of the cells, whole blood cannot be frozen and restored to liquid form for use. Plasma, the liquid part of the blood, because of the absence of the cells, can be kept in the liquid, frozen, or dried state. Before suitable drying methods were developed, attempts were made to keep liquid plasma by adding a preservative and sealing it, but this method has not been entirely successful. Plasma can be frozen satisfactorily and kept in the frozen state until it is thawed for use. This process obviously requires less equipment than drying, but it has the apparent disadvantage of the necessity for providing refrigerating equipment for storage. Transportation of frozen plasma is also a problem for the same reason.

The ideal method for preservation is to convert the liquid plasma into a dried form, retaining all of its ingredients except water which, when removed from the frozen material, does not change any of the essential elements. When reconstituted with pyrogen-free water, a plasma identical in all characteristics with the original is produced.

Very little has been published regarding the various methods for the preparation and desiccation of human plasma into its final powder form. Many interesting engineering principles are involved in the various methods now in use both in the Army-Navy program and in private use. It is the purpose of this paper to discuss the engineering phases of the desiccation of human blood plasma; from the liquid plasma state after separation from the cells to the dry powder which is packaged for distribution. Nothing will be included with reference to the collection of blood, the separation of plasma from the cells, or the prefreezing of the liquid plasma preparatory to drying. Obviously, nothing related to the administration of the reconstituted plasma with pyrogen-free water will be covered, as this falls within the field of medicine.

HISTORY OF PLASMA DRYING

The earliest record of work in this country dates back to 1909, when Shakell (1)[1] determined the fundamental principle of vacuum desiccation from the frozen state, which is so essential to the production of a highly soluble product with retention of its original properties. He also encountered the basic problem of this type of dehydration, namely, how to deal with the huge volume of water vapor released from only a few cubic centimeters of ice under the high-vacuum conditions necessary to this process. Shakell solved this problem by chemical absorption and set a precedent followed by many investigators since. His choice of sulphuric acid for a desiccant as well as the design of his machine definitely limited its use. Other workers using chemical absorption were Elser, Thomas and Steffen, and Flosdorf. Greaves and Adair improved machine design but found their methods severely restricted by the characteristics of the chemicals used. In general, these difficulties were insufficient speed of absorption, dilution, scum formation, or other changes retarding the pickup of water vapor as the process proceeded. These difficulties increased with any increase in size of the apparatus. This, and the expense involved in using a new desiccant each time, limited the application of these processes. In quality, however, satisfactory products were obtained. Elser, for example, was able to preserve cultures of meningococci and gonococci in viable condition for 18 years (2).

In Europe, experimental work had been conducted prior to that time by two German doctors, W. R. Krause and Robert Kenk. Their work covered the field of chemical desiccation and the use of exhaustion pumps for the desiccation of organic substances, especially those of animal origin. This work is described in their patent No. 12642, A.D. 1905.

Flosdorf developed regenerable chemical desiccation (using dryrite, $CaSO_4$).

Hill and Pfeiffer developed controlled physical adsorption using silica gel (3).

DESCRIPTION OF PROCESS

The obvious reason for drying human blood plasma, any biological substance, or a food, is the removal of water and the retention of all essential elements. The simplest system of drying consists of applying heat at elevated temperatures either directly or indirectly until the desired quantity of water has been driven off. Vacuum methods of drying reduce this temperature level, depending upon the degree of vacuum; for example, at 2 in. abs pressure, water will boil off at 101 F, consequently, if this vacuum can be maintained the water can be removed without elevating the temperature of the material substantially above 101 F. Even this temperature will cause the destruction of essential components such as complement, proteins, etc. If the degree of vacuum is increased or, conversely, if the absolute pressure is decreased, this temperature level at which evaporation takes place can be reduced. As this pressure is reduced below 4.58 mm Hg (vapor pressure of ice), the process of removing water can still be accomplished, but as sublimation. When desiccating from the frozen state, the molecules oscillate about a fixed point so that removal of water

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[1] Numbers in parentheses refer to the Bibliography at the end of the paper.

Contributed by the North Texas Section and presented at the Spring Meeting, Davenport, Iowa, April 26–28, 1943, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

vapor directly from the solid to vapor is accomplished without passing through the intermediate liquid state and affecting in any way the material.

The process of desiccation from the frozen state consists of subjecting the material to be dried to an extremely high vacuum, applying a sufficient quantity of heat to cause sublimation, and supplying means for removing the condensable vapors and noncondensable gases at as great a rate as they can be liberated from the material being dried.

The material to be dried, in this case human blood plasma, may be placed in the vacuum chamber either in the liquid or the frozen state. When prefrozen, it is usually frozen in a shell formation covering the inner circumference of the container, the thickness of the shell depending upon the quantity to be dried and the bottle dimensions. When placed in the drying container in the liquid state, it is necessary to control the degree of vacuum in order to allow the noncondensable gases to escape gently. This operation is called degassing and proceeds until all noncondensable gases have been liberated, after which time the air-admission valve used for controlling the vacuum is closed, the material being subjected to the lowest possible absolute pressure, causing spontaneous freezing. One of the principal difficulties in the operation of equipment of this type is that of obtaining sufficient capacity to remove the tremendous flow of water vapor liberated.

Table 1 (4) indicates the volume of water vapor to be handled. In ordinary vacuum work, specific volumes of several hundred cubic feet per pound are usually encountered, but in this process specific volumes of several hundred thousand cubic feet may be encountered. It is the ability of the particular machine to handle this tremendous flow which determines its suitability for this work. The control of heat input is relatively simple and, in general, can be common to all types of apparatus.

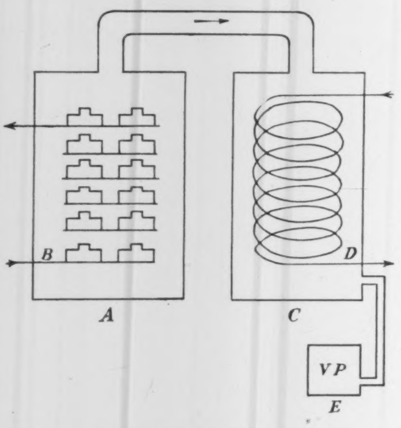

FIG. 1 SIMPLE DIAGRAMMATIC SKETCH OF APPARATUS

Fig. 1 illustrates in the simplest possible manner the arrangement of equipment necessary to dry from the frozen state. As illustrated, the vacuum chamber *A* indicates a single vacuum oven with shelves containing coil *B* (shelves are usually hollow rather than containing an embedded coil) through which a cooling or heating medium is circulated. As illustrated, heat is applied to them by means of fluid circulating through shelves *B*. This unit need not be limited to a single vacuum oven and may consist of a series of small ovens or manifolds with means for attaching the bottles directly. It may also consist of glass ampoules in which plasma is placed for desiccation. This sketch shows the arrangement of parts, the details of which can be varied according to the particular type of apparatus desired. There are five modifications of this system, each of which will be described. The methods are as follows:

1 *Direct vacuum pump (Desivac)*. For this arrangement the vacuum chamber *C* and cooling coil *D* are omitted, and a sufficiently large vacuum pump *E* is connected directly to the vacuum chamber *A*.

2 *Steam Jet*. In the steam-jet system, the vacuum chamber *A* is connected directly to a four-stage steam-jet booster compressor. The vacuum pump *E* becomes a two-stage jet, and the cooling coil *D* is replaced with a barometric condenser which removes the condensable vapors to a pressure level sufficiently high to cause condensation by direct contact with water. A two-stage jet is interposed between *A* and *E*, which compresses the vapors to a point at which they may be condensed by the barometric condenser *E*. No refrigeration is used to cool the water below the temperature obtainable from natural sources or cooled by evaporation. The noncondensable gases are removed by the steam jet at *E*.

3 *Cold Surface*. The cold-surface method is as illustrated in Fig. 1, with a sufficiently low temperature of coil *D* to establish sublimation by condensing the water vapor on it in the form of ice driven off from chamber *A*.

4 *Chemical Desiccation*. The vacuum chamber *C* now contains a chemical desiccant. No cooling coil is necessary, as the vapor pressure is constant up to the saturation point of the chemical and is not affected by changes in temperature.

5 *Physical Adsorbent*. The vacuum chamber *C* now contains a physical adsorbent, and cooling coil *D* is used for reducing the temperature of the adsorbent, thereby lowering the vapor pressure of the adsorbed water, and thus increasing the equilibrium capacity of the adsorbent.

It is apparent from the description of the various types of apparatus that methods 1 and 2 use a mechanical vacuum pump or a steam jet alone for the removal of water vapor, together with the noncondensable gases and entrained air. Methods 3, 4, and 5 use a supplementary medium for removing the water vapor and depend upon a vacuum pump for the removal of air and noncondensable gases. It is also apparent from this analysis that methods 1 and 2 are essentially constant-flow devices, the rate of vapor flow being limited to the capacity of the vacuum pump or steam jet used for drawing off the vapor. Methods 3, 4, and 5 are essentially different in their characteristics as the rate of vapor flow in these cases can be controlled entirely by the rate of heat input to the material being desiccated and is not limited to the capacity for removal of vapor of a specific pump.

TABLE 1 PROPERTIES OF SATURATED SOLID, VAPOR[a]

Temp F, t	Pressure, psi abs, p	Specific volume: Sat. solid, V_1	Specific volume: Sat. vapor, $V_g \times 10^{-3}$	Enthalpy: Sat. solid, h_i	Enthalpy: Subl. h_{ig}	Enthalpy: Sat. vapor, h_g
32	0.0885	0.01747	3.306	—143.35	1219.1	1075.8
30	0.0808	0.01747	3.609	—144.35	1219.3	1074.9
25	0.0640	0.01746	4.508	—146.84	1219.6	1072.8
20	0.0505	0.01745	5.658	—149.31	1219.9	1070.6
15	0.0396	0.01745	7.14	—151.75	1220.2	1068.4
10	0.0309	0.01744	9.05	—154.17	1220.4	1066.2
5	0.0240	0.01743	11.53	—156.56	1220.6	1064.0
0	0.0185	0.01742	14.77	—158.93	1220.7	1061.8
—5	0.0142	0.01742	19.04	—161.27	1220.9	1059.6
—10	0.0108	0.01741	24.67	—163.59	1221.0	1057.4
—15	0.0082	0.01740	32.1	—165.89	1221.1	1055.2
—20	0.0062	0.01739	42.2	—168.16	1221.2	1053.0
—25	0.0046	0.01739	55.8	—170.40	1221.2	1050.8
—30	0.0035	0.01738	74.1	—172.63	1221.2	1048.6
—35	0.0025	0.01737	99.3	—174.82	1221.2	1046.4
—40	0.0019	0.01737	133.9	—177.00	1221.2	1044.2

[a] Bibliography (4).

In method 4 the effective vapor-removal capacity is a function of the ratio of quantity of chemical desiccant to the quantity of water to be removed. In method 5 the vapor-removal capacity is a function of the ratio of the weight of the adsorbent used to the amount of water to be removed, together with the effective temperature control of the adsorbing medium which effective temperature determines its vapor pressure.

The proper selection of a vacuum pump is most important in methods 3, 4, and 5.

Vacuum Pump. In cases 1 and 2, all air and noncondensable gases are removed along with the vapor. For cases 3, 4, and 5, each uses an independent means for condensing the water vapor and depends upon a vacuum pump for the removal of air and noncondensable gases. While the minimum temperature at which sublimation of the ice is possible depends only upon the partial pressure of the vapor surrounding it, the rate of sublimation is affected adversely if the total pressure is materially greater than the vapor pressure. Thus, to obtain as rapid sublimation as possible, all entrained air, gases liberated from plasma, and gases admitted through leakage should be reduced to a minimum by a suitable vacuum pump.

The vacuum pump has two functions, i.e., to remove the entrained air as quickly as possible (for prefrozen operation) and to take care of any leakage, etc. An ideal arrangement is to employ a two-speed motor, using the high speed at the beginning of the run, and the low speed later. Too small a pump capacity will lead to difficulties by allowing partial melting or fusion in the early stages of the run, and too large a pump will not permit as low an absolute pressure as possible at the end of a run. When the pump capacity is larger than the available noncondensable gases, the pump will begin to handle water vapor, which will become condensed in the oil of the pump. Even with means for removing part of this water, the system tends to inherit the undesirable characteristics of system 1, and regardless of the effectiveness of the vapor-removing medium the pressure in the system is limited by the pump.

Drying Containers. From the standpoint of efficiency and rapidity of drying, the size, shape, and material of the container are very important. Obviously, the maximum drying rate can be obtained by a container having a maximum exposed surface in proportion to the volume of plasma to be dried. Neglecting all other considerations such as bacteria control, sterilization of equipment, etc., the ideal method would be to put the plasma in a flat tray to as thin a depth as practical. This has obvious disadvantages. Glass ampoules and bottles are very satisfactory for drying, in which case the ratio of the volume of plasma to the size and shape of the ampoule or bottle is important.

There are two general types of drying containers, one type of which dries the plasma in its final container and the other type dries it in a container especially designed for maximum drying efficiency and then transfers it into a final container. The obvious advantages of the first method, that is, drying in the final container, are (*a*) the elimination of additional time and labor required for transference, (*b*) elimination of possibility o bacterial contamination during transference, and (*c*) elimination of the possible increase in the moisture content during filling. The disadvantage of this type is that the bottle selected for drying either will be too small for rapid drying or too large as a final container.

The size of the bottle selected for the Army-Navy drying program represents a compromise between the loss of efficiency for drying and the smallest possible size to contain the final powdered plasma.

The obvious advantage of the second method is that the glass ampoules or metal trays of maximum surface per unit of volume can be used to assure complete dryness in the minimum time as the layer thickness of the plasma is materially less than in the first case. The disadvantages of this type are (*a*) additional time and labor required for transference to a final container, (*b*) possibility of contamination during transference, and (*c*) possibility of increase in moisture content during transference. With properly controlled conditions these disadvantages can be kept to a minimum.

The type of containers used at Baylor University Hospital are in the second group; namely, the most efficient size and shape for rapid drying and a transference of the dried product into the smallest feasible package. The Army-Navy program has adopted a drying bottle measuring approximately 5 in. long and $2^7/_8$ in. OD, having a capacity when full of approximately 400cc (495cc = 1 pint) in which the 300cc of citrated human plasma is placed. When prefrozen prior to drying this forms a shell thickness of approximately $^3/_4$ in.

GENERAL CONSIDERATIONS COVERING VAPOR FLOW

The generally accepted empirical formula for calculating the flow of saturated steam or water vapor is Grashof's; namely, $F = 60 \times P^{0.97} \times A$, where F = flow, lb per hr; P = absolute pressure, psi; A = orifice area, sq in. This formula is used by most leading designers of steam equipment. It is applicable for pressures ranging from the highest operating pressure down to the low-pressure region where the mean free path of the molecule is equal to the diameter of the orifice (5). The mean free path of the molecule at 1 mm is 0.08 mm, which is well below any dimension used. Below this pressure the relations in Grashof's formula may not necessarily apply.

Most of the work in the removal of water vapor from frozen plasma deals with superheated rather than saturated water vapor, but as the correction for superheat is relatively small and the means of measuring this is not usually observed, this correction factor will be neglected. One very important consideration which has been overlooked by experimenters in this field is the fact that here is a critical pressure ratio occurring when the downstream or final pressure is less than 58 per cent of the initial pressure. When this lower pressure (designated as P_2) is below 58 per cent of P_1, the vapor reaches a critical velocity, and further lowering of P_2 has no effect on the rate of flow. When P_2 exceeds 58 per cent of P_1, flow becomes restricted. The correction for restricted flow is given by the following formula (Grashof's)

$$K = 2.18 \times \sqrt{x(1-1.19x)}$$

where

$$x = \left(1 - \frac{P_2}{P_1}\right)$$

This K factor is included in the basic formula for unrestricted flow.

In terms familiar to the field of drying plasma, this means that, if the plasma is dried in a bottle where an absolute pressure of 1 mm is maintained and water vapor is being driven through the neck of the bottle to a lower pressure level, if the pressure in this lower level is approximately 580 μ, a maximum rate of water-vapor flow in the bottle is obtained. Whether this lower pressure level is 500 μ or 5 μ has no effect upon the rate at which the water is removed. This important factor has been overlooked by most experimenters in the plasma field, and some patents have been issued which are based upon statements directly opposed to the well-known laws governing the flow of vapors.

DESCRIPTION OF APPARATUS FOR FIVE METHODS

1 *Mechanical Vacuum Pumps.* Some manufacturers have advocated the use of rotary vacuum pumps, oil-sealed, and provided with means for separating the entrained water from the oil as a method for drying plasma from the frozen state. It appears that using a vacuum pump directly connected to a vacuum oven is a very simple apparatus. Table 2 shows what is called "an effectiveness factor" for the operation of a typical vacuum-pump system, which may be defined as the actual ratio of the weight of water vapor removed per unit of time to the weight of water vapor removed at 4.5 mm. Column 3 of Table 2 gives the specific volume of saturated water vapor for the various pressure and temperature levels indicated in columns 1 and 2. Column 4 is the inverse ratio of the increase in specific volume,

as compared with the volume at 4.5 mm. Column 5 gives typical volumetric efficiency for a pump of this type (1). Column 6 is the ratio of the volumetric efficiency compared with that at 4.5 mm. The product of columns 4 and 6 gives the effectiveness factor shown in column 7. This means, for example, that the vacuum pump when operating at 1 mm (representing approximately 0 F) would be handling vapors having a specific volume of 14,800 cu ft per lb as compared with the specific volume of this vapor of 3300 cu ft per lb at 4.5 mm. As the pump is inherently a constant-volume machine, the capacity compared on the weight basis is reduced to 22 per cent when operating at 1 mm, as compared with 4.5 mm. Its volumetric efficiency decreases, however, with lower pressure, dropping from 62 to 25. Consequently, the effectiveness of this pump for removing water or water vapor at 1 mm would be reduced to 9 per cent.

Further study of Table 2 indicates that the effectiveness of this pump is reduced rapidly until, when operating at a temperature of —30 deg or 0.178 mm, it has but 0.5 per cent of its original capacity at 4.5 mm. It is obvious from further study of this table that pumps of this type will operate down to a certain pressure level, below which they cannot go, so long as the amount of water vapor remains constant. An apparatus of this type is only satisfactory where a small quantity of plasma is dried with a large pump.

2 *Steam Jet*. Realizing the limitation that mechanical vacuum pumps have inherent decreasing volumetric efficiency at reduced pressures, efforts were directed toward utilizing the steam jet.

The steam jet in one form or another is familiar to most engineers and is used extensively in power plants for the removal of air and noncondensable gases in steam condensers. It has been used with some degree of success in refrigeration work, more particularly in northern climates where cold water is available.

The use of steam ejectors for compressing water vapor was suggested by Sir Charles Parsons about 40 years ago (2). He states that his invention consists of employing vacuum intensifiers (boosters) of the steam-jet type arranged to effect cooling, by evaporation of water vapor from the body of water to be cooled. For steam-jet refrigeration, single-stage jets are usually employed. Water is evaporated at a low pressure by the ejector action of the steam jet and discharged at a pressure high enough to permit condensation by water at ordinary temperatures. It would be physically possible to compress vapor all the way to atmospheric pressure using a relatively enormous quantity of steam in successive boosters. This is unnecessary, however, because with either a natural or artificial supply of cold water, it is possible to condense the steam around 28 in. vacuum or 2 in. absolute pressure.

The heart of the system is the steam-jet booster. In this, steam issues from the nozzles at velocities up to 4500 fps, draws in the cold vapor by aspiration, and compresses the entire mass within the throat and diffuser of the ejecter. The application of this apparatus in the field of desiccation from the frozen state necessitates working at an absolute pressure of 1 mm instead of the approximately 0.3 in. to 4 in. used in ordinary commercial refrigeration or air-conditioning work. This type of equipment has found many successful applications to processes requiring large quantities of moderately cold water (approximately 40 to 60 F). Because this process requires large quantities of condensing water, however, it has been generally impractical in the South. It has the advantages of being simple, free from many moving parts, and once adjusted requires little attention while in operation.

The steam jet has the disadvantage of being limited to larger installations where steam of suitable pressure is available. It is particularly sensitive to decreases in initial pressure or increases in back pressure due to higher-temperature cooling water, and, under conditions of excessive back pressure, it may even fail to function entirely. This characteristic is inherent in the nature of pressure by kinetic action. If the condenser were designed for 80-deg water and 1.4 in. back pressure, an increase to 90 deg would increase the back pressure to 1.9 in. (allowing 10 deg terminal differences). With a 0.5-mm evaporator pressure, the ratio of compression demands of the booster would be increased from 72 to 97. Not only the total compression ratio might be excessive but also, because of interstage condensers, the compression ratio of the various stages could become excessive. This means that the manufacturer who originally designed the jet for a given compression ratio would find his steam-consumption guarantee higher under changing operating conditions. The steam-jet booster may under these conditions break back, and it may be unable to compress its own burden or even a small quantity of vapor through a new and higher range of compression. This instability may continue until its evaporating pressure has increased by a sufficient amount to reach a compression ratio which the equipment is designed to attain. For like reasons, if the available water supply is less than 80 deg, a lower compression ratio is attained, resulting in lowered steam consumption and greater capacity. For example, if water at 70 F is available, the compression ratio becomes 52, as compared to 72 with 80 F water. The steam jet has proved satisfactory where properly applied.

TABLE 2 DERIVATION OF EFFECTIVENESS FACTOR

1	2	3	4	5	6	7
		Specific volume		Volumetric efficiency		
Temp F	Pressure, mm-hg abs	M cu ft per lb	Per cent	Actual per cent	Per cent of 4.5	Effectiveness factor
32	4.58	3.3	100	62	100	1.00
30	4.18	3.6	92	60	97	0.89
20	2.60	5.6	59	46	74	0.40
10	1.59	9.0	37	34	55	0.20
0	0.96	14.8	22	25	40	0.09
—10	0.56	24.6	13	17	27	0.04
—20	0.32	42.2	8	11	18	0.01
—30	0.18	74.1	4	7.5	12	0.005
—40	0.10	133.9	2	5.0	1	0.002

3 *Cold Surface*. The cold-surface method for desiccation from the frozen state is probably one of the oldest methods known. This method consists of providing a surface sufficiently low in temperature to condense the water vapor directly in the form of ice without passing through the intermediate liquid state. In order to do this effectively, the surface temperature must be very low, usually from —40 F to —100 F. This type of equipment can be divided into two general classes, i.e., those employing dry ice as a means of obtaining a low surface temperature, and those employing direct refrigeration. For the direct-refrigeration type, direct-expansion Freon units have been found satisfactory.

The dry-ice unit is probably the simplest of all types, consisting of a small condenser which is cooled by dry ice in a suitable fluid medium and connected directly to a chamber in which the plasma is placed, usually prefrozen. A small vacuum pump is then used for removing the air and noncondensable gases. This system is simple, inexpensive, and fairly satisfactory for small quantities, but its cost of operation is a limiting factor in the large units.

The large-sized units usually employ a direct-expansion refrigerant as the cooling medium, using suitable coil or tubing arrangements. The amount of surface is very important because of the insulating effect of ice forming on the coils. This factor is well known to refrigerating engineers. Unless due consideration is given to this effect, a condenser having an adequate amount of coil surface based upon clean coils would be entirely inadequate when a layer of ice has been formed upon these coils. This insulating effect can be partly overcome by reducing the evaporating temperature of the refrigerant used in the coils, but this is expensive and often difficult to do unless there is sufficient margin of excess capacity in the refrigerating system.

The freezing time varies as the square of the thickness of the ice, all other conditions remaining constant, and the freezing time varies inversely as the temperature difference between the ice surface and the evaporator temperature (8).

In order to illustrate this application to the design of the cold-surface condenser, assume a condenser having 100 linear ft of 1-in-OD tubing. This will give an outside-diameter coil surface of 2.18 sq ft. Assume further that it is desired to maintain 1 mm Hg absolute pressure in the vacuum chamber in which the plasma is placed. In order to obtain maximum vapor flow, the absolute pressure in the container chamber should not exceed 0.58 mm Hg abs, which is the vapor pressure equivalent of the ice-surface temperature of —10 F. As an example, assume an average *K* factor of 3 Btu per sq ft per deg F per hr (typical for air to liquid through coils) with a maximum ice thickness of $^1/_4$ in. This will represent 2.7 lb of ice on the 100-ft coil and will assume a total operating time of 63 hr. The necessary temperature difference to accumulate the ice thickness in this time would be

$$t_d = \frac{1221 \times 2.7}{3 \times 63 \times 2.18} = 80 \text{ F}$$

To maintain an effective ice-surface temperature of —10 F an 80-deg temperature difference would require an evaporation temperature of —90 F. This *K* factor, of course, would be higher at the beginning of the run when the coils were clean and lower at the end when the ice thickness is greatest. If it is desired to increase the vapor-removing capacity of this machine without increasing the effective surface of the condenser, it will then be necessary to increase the mean temperature difference between the outside ice surface and the evaporator in the coils. It would not be necessary to maintain this extremely low surface temperature of the coils at the beginning of the run; but in order to maintain the condenser in effective condition it would be necessary to decrease the evaporator temperature to offset the increasing insulating effect as ice forms on the coils. The flow of vapor is not always constant and can be varied at will depending upon the design of the equipment.

4 *Chemical Desiccation*. Chemical desiccation was probably one of the oldest methods used, as records dating back to the last century disclose apparatus designed to dry biological substances from the frozen state (9). Some of the earliest experimenters used sulphuric acid and phosphorus pentoxide as the chemical desiccant. These chemicals exhibit a marked affinity for water vapor under abnormally low vapor pressures, and this quality makes it possible to effect the removal of water vapor under the extremely low pressures necessary for sublimation. The apparent disadvantages of using these chemicals were (*a*) that they are not regenerable and therefore could be used only once, (*b*) they were difficult to handle, and (*c*) their capacity for the removal of water vapor was relatively small. Later development led to the use of calcium sulphate which was regenerable. For example, the present commercial calcium sulphate sold as dryrite can be regenerated as many as 15 to 16 times.

Calcium sulphate because of its ability to be regenerated has replaced the older chemicals and has been used somewhat in this field. Its application is limited to the smaller installations, as recommended by the builders of equipment of this type. Chemical desiccation has some advantages over methods 1, 2, and 3 for small installations in that less expensive equipment is required, and its operation is simpler than either method 2 or 3.

5 *Physical Adsorbents*. As indicated in the description of this method, physical adsorption differs from the chemical desiccation of method 4 by using a physical adsorbent such as silica gel, or similar substance, and by cooling effectively to control the temperature and, consequently, the vapor pressure of the adsorbed water, thereby greatly increasing the capacity of the silica gel for adsorbing water throughout the cycle. In this method, as in method 4, the desiccant can be regenerated by passing a quantity of heated air throughout the mass until all of the adsorbed moisture has been removed.

The physical-adsorption method represents an ideal one having advantages over all other methods in some phase of its operation. It is comparable in effectiveness with the cold-surface and the chemical methods in small installations. It is flexible and compact. An apparatus can be designed from the smallest laboratory size up to unlimited capacity. In order to differentiate this method from others, the term "adtevac" has been coined by its inventors, Hill and Pfeiffer, to describe it in a single word. This term is the abbreviation of three words, i.e., adsorption, temperature, and vacuum.

Its principal advantage over the chemical method is the increased capacity; over the cold-surface method, its decreased investment and operating cost; over the steam-jet method, its flexibility in that it can be operated at any location; and over the mechanical-vacuum-pump method, its capacity and quality of the final product.

INSTRUMENTS

In the operation of any of the apparatus which has been described, a satisfactory result usually depends upon a control of temperature and pressure consistent with good practice. The measurement of temperature, both directly and remotely, is relatively simple, and there are many standard thermometers suitable for this work. When obtaining the temperature within the vacuum chamber, obviously care must be taken in the method of bringing the thermometer lead through the vacuumtight container, but other than this no unusual difficulty is encountered.

The measurement of pressure is more difficult, as unfortunately no standard pressure-measuring devices are available which will indicate the true total pressure in the range encountered. Direct methods for measuring pressure are not sufficiently sensitive to be of any value below several millimeters of mercury absolute pressure. Consequently, it becomes necessary to use indirect methods.

One of the indirect methods used is the McLeod gage which operates on the principle of volume measurement. In this method, a known volume of the gases, whose pressure is to be measured, is compressed through a given pressure range, the pressure then being indicated in terms of the decreased volume. This method is satisfactory for noncondensable gases and is commonly used for detecting air leaks. It is of little value for the measurement of water vapor where the compression ratio is sufficiently high to cause condensation. Obviously, if the sample were entirely water vapor, a reading of a very few microns would be obtained which would simply be an indication of the partial pressure of the noncondensable gases in the sample measured. Another sample taken near the vacuum pump might consist of noncondensable gases largely and indicate a considerably higher reading than the previous sample which should be in a higher pressure range. Because of this fact, all measurements of pressure should be designated by the method used.

By the installation of a cold trap in the line to the McLeod gage, condensable vapors can be condensed out before reaching the gage. In this manner, the McLeod gage can be made suitable for measurement of total pressure. This cold trap can be either a liquid-air or dry-ice type. The disadvantage of either of these methods is that the condensed liquid in the gage line will ultimately freeze, thus obstructing the line and making it impossible to obtain true pressure readings. If this method is used, periodic cleaning of the pressure line is necessary. The interval between cleaning-out periods depends largely upon the percentage of water vapor in the sample being measured. Usually this period is approximately 10 days in this type of work.

Another method of obtaining true total-pressure readings is by means of a differential inclined manometer. This manometer can be made between two vacuum bottles, one of which is connected to a vacuum pump capable of producing 1 mm absolute pressure. The inclined type can be arranged at an angle of about 20 deg so as to make a 1-mm pressure which gives a scale deflection of 60 mm. A suitable fluid for this type manometer is dibutyl-phthalate.

Another procedure frequently used involves an indirect electrical method incorporating the Pirani gage. This gage depends for its operation upon the degree of heat emission from an electrical filament, the gage simply measuring the change of resistance of the filament by reading the change in current from a constant voltage. Unfortunately, the characteristics of this gage are such that its useful range is between 10^{-1} mm and 10^{-4} mm. For pressure above 10^{-1} mm, the sensitiveness of the gage decreases so rapidly that it becomes practically useless at 1 mm. It is effective only when the mean free path of the molecules is relatively large in proportion to the length of the filament (10).

A thermocouple-type vacuum gage has been built by several instrument manufacturers which has some advantages over the Pirani gage in that its effectiveness does not change so much with use. The Pirani-type gage is affected by the change in the resistance of the filament, which change could occur by carbonization of the filament. The advantage of any electric-type gage is that it measures true total pressure and not partial pressure of the noncondensable gases as does the McLeod gage.

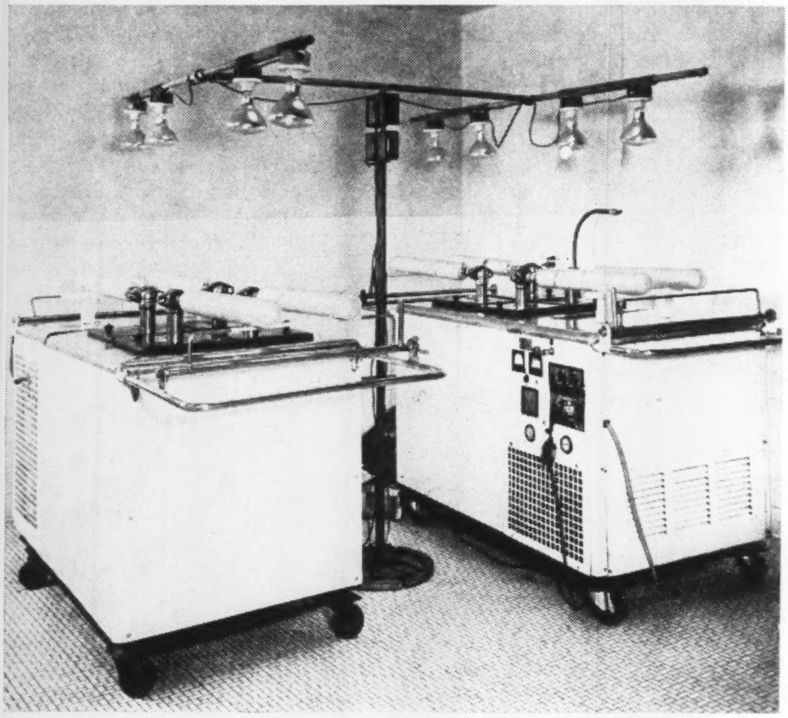

FIG. 3 TWO FOUR-UNIT ADTEVAC CABINETS

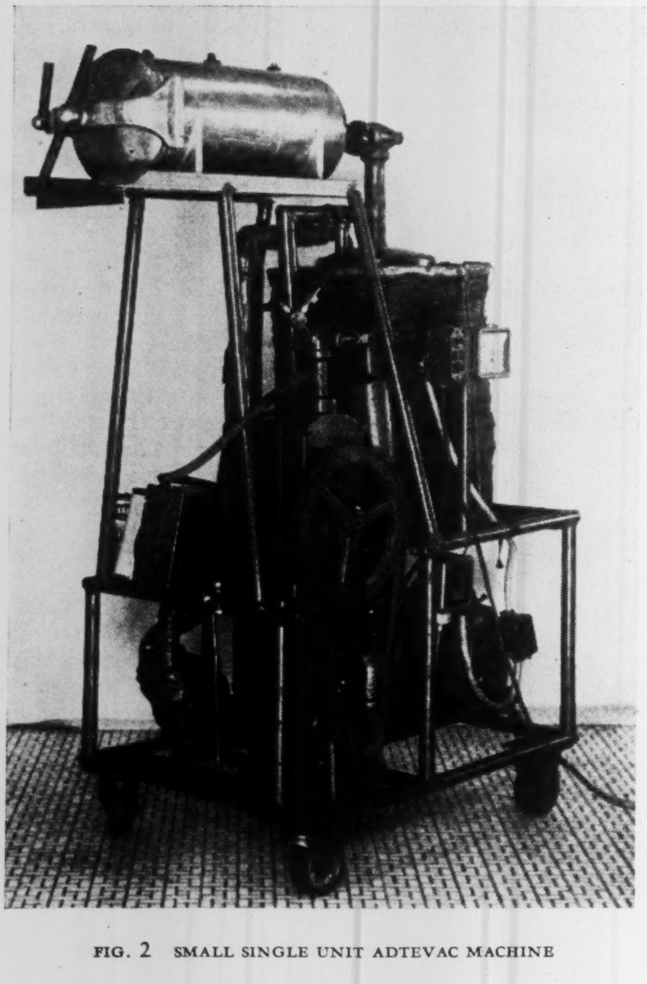

FIG. 2 SMALL SINGLE UNIT ADTEVAC MACHINE

An electric gage has been developed by Dr. Dayton Clewell of the Magnolia Research Department for the Baylor University Hospital Laboratories, in connection with the operation of its equipment. This gage has all of the advantages of the McLeod in that it is sensitive from 1 μ to 3 mm. It has a high- and low-range scale, the low-range scale operating between 1 and 500 μ, and the high-range scale operating between 0.5 mm and 3 mm. The advantage of this is to achieve greater sensitivity where most desired; for example, in vacuum testing work and for measurements near the vacuum pump, the low-range scale is most suitable, and for measurements in plasma containers or manifolds to which they are attached, where pressures in the range of 1 mm are encountered, the high-range scale is most effective.

DRYING UNITS AT BAYLOR UNIVERSITY HOSPITAL

Baylor University Hospital at Dallas, Texas, pioneer in the plasma-drying field, has for a number of years been the only hospital in the country having an available supply of dried plasma subject to call at any time. As early as 1938, a small unit was in operation capable of drying approximately 1500 cc per run. This unit has since been dismantled and replaced with a later and more efficient type of machine. The present equipment at Baylor consists of three drying machines as follows:

A small single-adsorber unit having a normal capacity of 1 liter per run and used primarily for research. This machine, Fig. 2, is essentially the same as the larger ones except for the vacuum chamber which, instead of consisting of glass ampoules, is a metal cylinder in which the complement or other biological substances are placed. Unlike the other machines, means are not provided for accelerating heat input into this miniature vacuum oven, other than by conduction through the metals. This usually is not necessary due to the small quantity of material being dried, as there is sufficient heat flow from conduction through the metal.

Fig. 3 shows the two desiccating cabinets which have been in normal use for the past 2 years. Each of these cabinets has

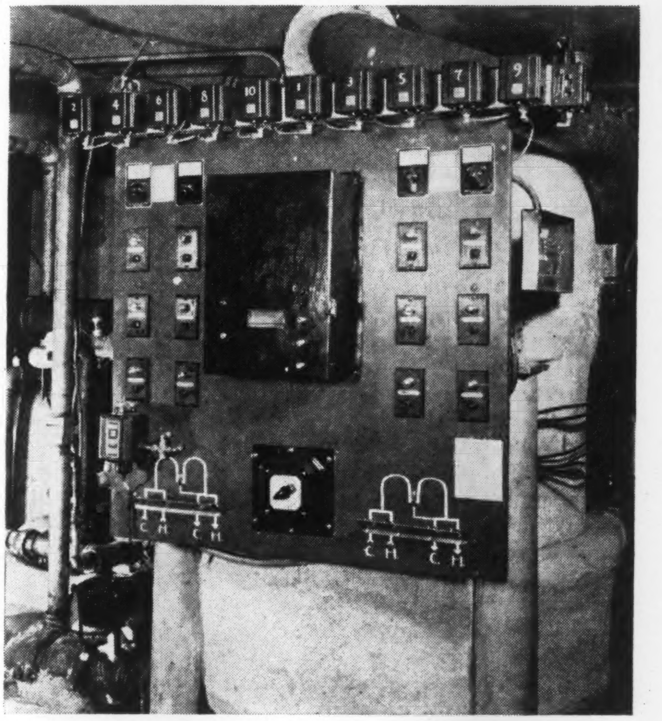

FIG. 4 CONTROL PANEL FOR 100-LITER ADTEVAC MACHINE

a normal rating of 3.2 liters per run, and the present operating schedule allows approximately $2^1/_2$ runs per week for each cabinet. The average production of these units has been approximately 50 to 60 liters per month. It is possible to obtain 4.8 liters per run by increasing the loading of the ampoules from 800 to 1200 cc. The cabinets consist of four adsorbers each, removable for regeneration. The silica-gel adsorbers are regenerated by placing them in an electrically heated oven and blowing a quantity of hot air through the adsorbers until the leaving air is dry. Cabinets of this type have been operated with complete satisfaction for several years and there has been no evidence of deterioration of the silica gel from continual adsorption and regeneration.

Fig. 4 shows the large oven-type machine built for the William Buchanan Blood, Plasma, and Serum Center. It has a normal capacity of 80 liters per run, and a maximum capacity of 100 liters per run. This unit is of the physical-adsorption type, designed by Hill and Pfeiffer. Instead of removing adsorbers for regeneration, as is done in the smaller units, this is accomplished in place. The unit consists of two adsorbers with the necessary valves and piping so that one adsorber can be used to remove vapors from the material placed in the oven while the other adsorber is being regenerated. Plasma is put in stainless-metal trays which are placed on the shelves of the vacuum oven; cooling or heating fluid is circulated through the shelves as desired to control the rate of drying. Fig. 5 shows a diagrammatic arrangement of valves and piping for the large unit.

CONCLUSIONS

1 Drying from the frozen state offers many advantages for preserving human blood plasma, compared with either liquid or frozen plasma.

2 Five methods of vacuum drying from the frozen state have been described. Careful consideration should be given to an analysis of all factors in the selection of any particular type of drying equipment.

3 The present drying program for the Army and Navy will undoubtedly encourage general commercial drying after the war. This will bring additional economical problems such as available supply of human blood, minimum investment for satisfactory drying equipment, and, with competition, a greater emphasis on cost of operation. The present program calls for the maximum quantity of satisfactory dried plasma for our Army and Navy, and all other considerations such as investment and operating costs are secondary.

4 The portable cabinet, such as is shown in Fig. 3, offers excellent means for the drying of human plasma now stored either as liquid or in the frozen state for civilian defense. These cabinets are economical in operation, and the dried plasma can be safely stored even during air raids when failure of electrical service would render the cabinet storing frozen plasma useless. The gradual melting and slow rise of temperature would accelerate precipitation of fibrin making the plasma very undesirable.

5 The more expensive methods of desiccating from the frozen state will undoubtedly find their place in the foods field, being limited primarily to more expensive foods, where the higher-quality product will justify the additional cost of dehydration.

ACKNOWLEDGMENT

The author wishes to acknowledge valuable engineering contributions from Hal Gibson, of the General Electric Company, Oscar Kelly, of the Boedeker Manufacturing Company, Logan Knapp, of the Dallas Power and Light Company, and Dr. Dayton Clewell of the Magnolia Petroleum Company.

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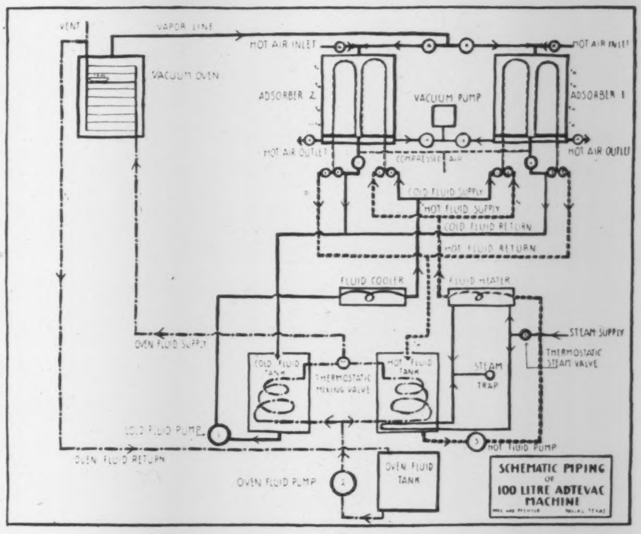

FIG. 5 DIAGRAMMATIC PIPING OF 100-LITER ADTEVAC MACHINE

How AIR CONDITIONING *Has Advanced* REFRIGERATION

By WILLIS H. CARRIER

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WHEN the next history of the refrigeration art is written, air conditioning will be given credit for most of its outstanding advances. Among these there are at least three which should rank as the greatest advances in the art since the inventions of Linde, less than seventy-five years ago. These are: (1) The development of a series of new and improved refrigerants, including low-pressure refrigerants; (2) the development of a low-pressure system of refrigeration, involving centrifugal compression; (3) improvements in performance and capacity of automatically controlled reciprocating compressors adapted to the new refrigerants.

The advent of new refrigerants and the centrifugal refrigeration system has brought about outstanding improvements in heat-transfer surfaces in condensers and evaporators. While the centrifugal compression system has been conspicuous in providing inherent control of temperature and capacities without gadgets, the new refrigerants have permitted, and the air-conditioning art has demanded, automatic controls and automatic expansion valves which have been perfected for the smaller reciprocating machines. All of these advances have been brought about, either directly or indirectly, by the demand and the extensive market afforded by air conditioning.

That one industry should play such an important part in the development of another industry is by no means a unique experience in the developments of the machine age. The need for power-driven pumps for coal mines brought forth the Newcomen engine, and the need for a new source of power to drive Arkwright's spinning machines made it possible for Watt successfully to develop and promote the steam engine. If it had not been for this ready-made demand, it is probable that the firm of Watt & Bolton would not have had sufficient business to keep them going, and the advent of the machine age would have been long delayed. In the case of the steam engine, it was this urgent need that brought about the introduction of a revolutionary process long before the underlying scientific principles were understood, for it was not until the next century that Carnot disclosed to the world the thermodynamic principles involved in the steam engine. It was even later before the mechanical equivalent of heat was appreciated or known. On the other hand, Faraday discovered and demonstrated the principles of the generation and utilization of electric power and even built a working model of an electric motor 50 years or more before these principles were put to any useful commercial purpose. It was 75 years after Faraday's discovery that the electrical age really became an economic factor in our economy. The obvious reason for this was that the market for electrical transmission did not exist at the time of Faraday.

Thus, it is seen that, between a fundamental demand for a product and the scientific knowledge of its requirements, the former is the most essential; in fact, the all-essential factor. On the other hand, an art never achieves its full potentialities, regardless of the market, until the basic principles of its operation are thoroughly investigated and understood. For example, with the knowledge possessed in Watt's day, it would have been impossible to develop the steam turbine. It required the scientific thermodynamic foundation provided in the last century by Carnot, Joule, Thomson, and others, to make this more refined development possible. Similarly, in the field of electricity, much physical and mathematical research was necessary to make possible the performances and efficiencies essential to the complete fruition of our present era of electrical transmission of power. In fact, it is these scientific studies, whether preceding or following practical applications, which are responsible for our present high state of mechanical and economic development.

LINDE'S MECHANICAL REFRIGERATING MACHINE

Prominent among the inventions, based on this recent knowledge of thermodynamic principles, is Linde's mechanical refrigerating machine, introduced within the memory of some now living. As will be appreciated, this machine is nothing but a heat pump, the basic principle of which is reversal of the heat-power cycle. Created to fill a need for cooling in brewing processes and in the manufacture of artificial ice, it has made for itself an essential place in our modern living and has become a great industry. With the aid of electric power transmission, it has made possible household refrigeration and air conditioning. Thus both of these industries owe a debt to the art of Linde. However, it is desirable to show how these two applications, especially the latter, have more than repaid this debt by advancing the very art which made them possible.

Up to 20 years ago, the refrigeration art had made little technical progress except in its applications. The same refrigerating machines and the same refrigerants were those that had been in use for fifty years. The standard refrigerants were still those chosen by Linde, i.e., ammonia and carbon dioxide. Ammonia was regarded as the ideal refrigerant because its pressures were not so excessive as those of carbon dioxide, its thermal cycle was highly efficient, and it was especially adaptable to the production of low temperatures. Apart from its thermal advantages, however, ammonia had several recognized limitations and disadvantages. Ammonia attacks nearly all nonferrous metals, with the exception of aluminum. As a result of this, practices in refrigeration were standardized to use steel or iron in many places where otherwise they would have been considered uneconomical and unsuitable. All condensers and coolers, for example, were of steel construction, whereas in practically all other heat-transfer equipment, except steam boilers, brass or copper tubing, because of better performance, increased life, and even lower first cost, had become a standard. Such a thing as a steel-tubed condenser was unthinkable in power-plant practice, whereas with ammonia it was imperative. The employment of automatic valves and control equipment was also at a disadvantage because of the necessity of all-steel construction, whereas in other arts the use of bronze diaphragms and valves was standard practice. Thus the art of refrigeration, for nearly 50 years, had been developed and built around inherent limitations of ammonia.

In general practice, all of the refrigerant was kept on the high-pressure side and was expanded as required into the cooling coils. With a reciprocating compressor, much oil was fed into the refrigerant, in which it was not soluble. As a result, the cooling surfaces as well as the condensing surfaces became fouled with oil so that the efficiency of a system long in use was

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greatly impaired. In large installations, a frequent cause of poor performance was the loading of the condenser with noncondensable gases which raised the back pressure and increased the power consumed. This was usually corrected by hand purging requiring operator attention. With positive compression, the temperature would drop whenever the load was reduced.

AIR CONDITIONING CREATES NEW REFRIGERATION REQUIREMENTS

When the existing systems of refrigeration came to be applied to air conditioning, it was necessary to use a construction for the cooling of the spray water which would not be subject to injury from freezing. Thus it was the general practice to distribute water on the outside of the expansion coil in what is known as a Baudelot cooler. This was cumbersome and mechanically deficient. In addition to mechanical disadvantages, there were other more serious drawbacks inherent in the use of refrigeration in air conditioning. In air conditioning for comfort, the use of ammonia was almost prohibited without exceptional and costly precautions to guard against its hazard in case of accident. It was necessary to use ammonia to cool brine, and the brine to cool the water for the air-conditioning equipment.

In air conditioning, carbon dioxide was safe, at least outside of the machine room, but it was not at all well adapted for summer operation. It required practically double the amount of power and twice the amount of condensing water as ammonia for the same conditions. Large air-conditioning systems necessitated the provision of cooling towers for the condenser water, but their use with carbon dioxide was almost precluded because, when the air-conditioning load was the greatest, the condenser-water temperature was often beyond the critical condensing temperature of carbon dioxide, and its efficiency and capacity dropped off with excessively great rapidity. While in air conditioning for comfort, carbon dioxide seemed at that time to be the only "out," it was an exceedingly poor one.

In the meantime, the demand for refrigeration for air conditioning was growing apace, and the advance of the air-conditioning art was being retarded for the want of a suitable system of refrigeration employing a suitable refrigerant. As early as 1910, the possibility of using Le Blanc's system of steam-jet refrigeration to cool the spray water was seriously considered but at that time was rejected because of its expense in first cost and operating cost, as well as its lack of flexibility.

In 1916, the author decided that if the air-conditioning art was to advance, especially in the "cooling-for-comfort" field, existing refrigeration practices would have to be completely abandoned and a new method of refrigeration developed to fulfill the following conditions:

1 Provide a system of nonpositive compression which will "float" on a varying load without automatic control.

2 Employ a safe low-pressure refrigerant adapted to such a system of compression which will not affect copper, brass, or steel.

3 Employ, as an integral part of the refrigerating machine, a water cooler which will operate exactly like a water heater so that the water can be cooled through any range of load practically to a constant temperature without any danger of freezing under light loads.

DEVELOPMENT OF THE CENTRIFUGAL REFRIGERATING SYSTEM

These requirements were fully met in 1921 by the development of the centrifugal refrigerating machine and the discovery of a new low-pressure refrigerant adapted to use with such a machine. While centrifugal compressors had been in use for ten years or more prior to that date, they were not then adapted to use in refrigeration because of the lack of the following essential elements:

1 A refrigerant of suitable properties.

2 A seal suitable for high-speed operation which would prevent inward leakage of air or outward leakage of the refrigerant whether operating or shut down.

3 An internal oiling system which would function satisfactorily with a miscible refrigerant gas and also avoid excessive loss of refrigerant.

4 An evaporator for cooling water which would avoid submersion of the tubes causing a serious loss in temperature head with a low-pressure refrigerant.

5 An automatic purging system for the removal of air in the system without serious loss of refrigerant.

For centrifugal refrigeration it was necessary to have a refrigerant that would have a large volume per unit of refrigeration, and at the same time a high molecular weight to facilitate centrifugal compression with few stages. Preferably, it should have boiling points above normal atmospheric temperatures so that it would not readily escape from the system, either when operating, shut down, or when the equipment was open for inspection. Fortunately, such a low-pressure refrigerant also would provide the large volume needed per unit of refrigeration.

The first refrigerant employed was dichloroethylene. At that time, it was the only compound being manufactured in commercial quantities which would meet all of these requirements. Its previous use had been as a solvent and it was only manufactured by one firm which had never before imported it for use in this country. Later, when the demands for refrigerant grew to considerable proportions, it was possible to arrange for the manufacture in this country of a still more suitable refrigerant, methylenechloride. These two refrigerants were used for about ten years until the present series of Freon refrigerants became available.

The centrifugal system of refrigeration included many other radical departures from existing refrigeration systems. The refrigerant expansion valve which had been a fixture in refrigeration for 50 years was discarded for a trap on the condenser with a simple float valve. The low-pressure refrigerant was distributed over the tubes by means of a pump and a distributing deck. The tubes were not submerged. The entire machine was close-coupled as a single unit, incorporating the evaporator, condenser, compressor, and drive.

Unfortunately, some of these improvements, notably that of the use of centrifugal compression for refrigeration, although never successfully reduced to practice, had been anticipated in the patent office by the expired patents of Le Blanc. In this connection, the author would like to correct a misconception which he finds to be quite prevalent. The centrifugal system of refrigeration was not introduced from abroad as many suppose. The first centrifugal machine used abroad was a 1000-ton ammonia compressor, installed about four years later than the first centrifugal refrigerating machine to be operated in this country. Ammonia is so ill adapted to centrifugal compression that its use is practically precluded. To the author's knowledge, only one such machine was ever built. About seven or eight years after the introduction of the centrifugal refrigerating machine in this country, a Swiss firm developed a design with a motor enclosed within the compression chamber, obviating the use of a seal and circumventing the American patents. This latter development did not receive any wide public acceptance.

GENERAL MOTORS DEVELOPS FREON REFRIGERANTS

The availability of a simplified and safe refrigerating system resulted in a rapid advance in air-conditioning applications of the larger capacities to theaters, department stores, hotels, etc., an advance which would have been impossible had we to contend with the disadvantages of the older standardized types of refrigeration. The installation of large air-conditioning systems accelerated rapidly for more than a decade. Then the need for a better and safer refrigerant for household refrigerators and for smaller air-conditioning units became evident. This led Midgely to develop a series of Freon refrigerants which were to accomplish for small refrigerating equipment what the low-pressure refrigerants and the centrifugal machine had accomplished for large air-conditioning installations.

The advent of these new refrigerants also brought large-size reciprocating compressors into competition with the centrifugal machines for air conditioning. Fortunately, however, for the centrifugal machine, the Freon series of refrigerants provided a wide range of pressure-temperature relationships, and one of them, F-11, was ideally adapted to existing centrifugal equipment. With this new refrigerant both the number of stages and the size of each stage could now be reduced approximately one half. This immediately permitted the further invasion of centrifugal machines into the low-temperature field of refrigeration which, up to this time had been considered the exclusive field of the reciprocating machine. Within 3 years after the introduction of the Freon refrigerants in 1932, centrifugal machines were producing refrigeration at —100 F in the production of artificial rubber, a development which was beyond the range of standard refrigeration practice with ammonia or carbon dioxide.

Now, war requirements have made it possible to develop centrifugal compressors of large capacities for F-12 with four stages in one housing, which operate between a range of —55 F in the evaporator to +100 F in the condenser, or from —67 F to +86 F. These machines have a normal ratio of compression of 25 and will work between 15 to 25 with high efficiency.

EFFICIENCY OF CENTRIFUGAL COMPRESSORS

Formerly the centrifugal compressor was considered to be inherently less efficient than the reciprocating compressor. Actually the reverse is true. The change in design of the compressors to use the new Freon refrigerants gave opportunities for design research which greatly improved the efficiency. Rotor efficiencies as high as 94 per cent are now reached, and over-all efficiencies above 80 per cent under best operating conditions are achieved. The ceiling for the over-all efficiency of centrifugal compressors appears now to lie between 85 and 90 per cent. This need not seem surprising to those familiar with the remarkable strides made in the efficiency of the centrifugal pump. It was once thought that 70 per cent efficiency was good and probably 80 per cent the ultimate in efficiency for these pumps. Today, the best efficiencies are above 90 per cent.

Moreover, multistage centrifugal compression has opened the way to important economies not found in the single-stage reciprocating refrigeration system. These economies offer especially great possibilities with the new refrigerants, whether of the low-pressure or the high-pressure group. These refrigerants which are all of relatively high molecular weight have relatively low latent heat, as compared with the specific heat of the liquid. On this account, important economies can be obtained by stage-cooling of the liquid from the condenser to the evaporator. In centrifugal compression, this is done in one or more economizers in which the flash gas is introduced between the stages. The use of the economizers for the reduction of liquid temperature results in decreasing the power from 5 per cent or more in a two-stage machine used in air conditioning, up to as much as 25 per cent in a four-stage machine for low-temperature refrigeration. As a result of these efficiencies and applications, it is possible to produce 1 ton of refrigeration for any stated range of temperature with less power with a centrifugal machine than with the usual reciprocating system.

APPLICATIONS OF CENTRIFUGAL COMPRESSION SYSTEM

The requirements of blackout plants and special process work during the war have required large air-conditioning installations with large refrigerating plants. These have been, almost without exception, centrifugal plants. Above certain sizes centrifugal refrigeration is not only more economical to operate but has proved less expensive to install than reciprocating machines using refrigerants other than ammonia. Thus for large air-conditioning plants, centrifugal compression systems are now standard practice. They are also exceptionally desirable for all temperature ranges in plants using process steam, because the compressor can be directly driven by turbines which act as reducing valves from high to low pressure required for "process" work. They are also highly economical when operated with exhaust-pressure turbines which utilize low-pressure steam from other parts of the plant. Thus, above certain sizes and for many applications, centrifugal refrigeration has become almost overnight the accepted standard.

Centrifugal machines, however, are not well adapted for smaller units. At some point in the reduction of capacity, the reciprocating machine surpasses the centrifugal machine both in first cost and performance for equal capacities. Great improvements have been brought about in these smaller reciprocating units largely because of the requirements for their use in air conditioning. Units up to 60 tons or more capacity are made as self-contained units for direct-expansion cooling, or for cooling brine or water for air conditioning and other purposes. These are, for the most part, multicylinder machines wholly automatic both as to starting, stopping, and capacity variation. Machines of this size have the advantage in that they can be thrown in directly on the line in most installations. Some of these machines have motors enclosed within the compressor shell, but the majority use independent motors with a seal which has been perfected since the advent of the Freon refrigerants. These seals have been developed to be practically foolproof and obviate the necessity of the built-in motor.

REFINEMENTS IN COMPRESSOR PRACTICE

Compressors have been redesigned so as to give smooth operation and good efficiency at high speeds. The weight of a compressor, per ton of refrigeration, has been reduced to possibly one third its former weight. Great advances have been made in controls and automatic expansion valves where bronze diaphragms and fittings can be used to advantage under moderate pressures. The cost of such accessories has been greatly reduced because of the large market afforded by air conditioning.

Another great advance which was first applied to centrifugal machines and later quite generally to reciprocating machines is the replacement in evaporators and condensers of plain tubes by "Lo-Fin" tubes. The Freon refrigerants have a low heat-transfer coefficient, as compared with other refrigerants such as ammonia, for example. For this reason, it is desirable to increase the surface on the outside of the tubes in contact with the refrigerant. In the Lo-Fin tube, the fins are extruded by a special machine on the outside of the tubes, thereby increasing the external surface $3^1/_2$ times or more. This has resulted in decreasing the number of tubes required to less than one half and, at the same time, in improving the performance. This has permitted a great reduction in weight and space occupied of both the evaporator and condenser, and has made possible a much more compact self-contained construction.

The saving of space and weight are prime requisites in most air-conditioning applications as, for example, in the completely self-contained air conditioner for use in smaller stores, restaurants, etc. These self-contained units have reduced the cost of such installations to less than one half of what it was before modern designs were perfected. Such installations were only made possible by the use of a safe refrigerant and a greatly reduced space requirement.

The advances which have been made in refrigeration, as a result of air-conditioning demands, have been made available for many other applications of refrigeration as in cold storage, breweries, meat-packing houses, and chemical processes. These advantageous applications would not have been possible without the incentive afforded by air conditioning for basic improvements in the art of refrigeration. On the other hand, without this development in refrigeration, the extraordinary advance in the art of air conditioning both in industrial processes and in comfort cooling would have been impossible. In other words, air conditioning and refrigeration have been mutually dependent upon each other for the great advances that have been made in these arts during the past two decades.

Future Possibilities of
DIESEL ROAD LOCOMOTIVES

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THIS paper has two major objectives. The first is to establish the advantages, both in performance and in economies of operation, that will be gained by a reduction in locomotive weight. The second objective is to suggest ways and means of accomplishing this weight saving. Economies in operation can be seriously and adversely affected by any sacrifice in reliability, or by excessively high maintenance costs. Because of this, no radical or untried engineering will be proposed.

In the speed range above 20 mph, the available tractive force of a road locomotive for either freight or passenger service is limited to the power developed by the Diesel engines. This is not sufficient to produce maximum tractive force in the high-speed range.

Maximum tractive effort for any locomotive can be attained by making all axles driving axles, but the weight of present Diesel road locomotives makes this method impractical and in fact of little advantage in the over-all performance of the unit. In spite of the possibilities of large weight saving, however, it is doubtful if a road locomotive will ever be light enough to make its starting and low-speed performance unsatisfactory.

EFFECT OF WEIGHT SAVING BY COMPARISON OF PERFORMANCES

Table 1 gives a number of factors which describe some of the characteristics of two locomotives. Locomotive *A* is an existing unit of 6000 hp. Locomotive *B* is a unit intended for the same service and to give approximately the same performance. The two outstanding differences are a reduction of weight of 275,000 lb and a reduction in horsepower of 750. Further reference to this table will be made after comparisons of the performance curves are completed.

Fig. 1 shows a series of curves which compare several performance factors of the two locomotives whose characteristics are outlined in Table 1. Curves 1 and 2 are the available tractive effort of locomotives *A* and *B*, respectively. Numbers 3 and 4 are resistance curves of each locomotive plus a trailing load of 15 cars weighing 66 tons each. It will be noted that these cross at 100 mph for the *A* powered train, and for the *B* powered train, 97.5 mph. These maximum speeds are for equal trailing or revenue-producing capacity. The *B* unit is 750 hp less than the *A* unit and, obviously, is the more economical to operate. The difference in maximum speed of the two trains, both on level track, as well as on grades, is so small that differences in the mechanical, electrical, or track conditions would produce performance variations of greater magnitude than are indicated by these curves.

Curves Nos. 5 to 10, inclusive, Fig. 1, indicate the total train resistance on $^1/_2$, 1, and $1^1/_2$ per cent grades. They illustrate the value in weight reduction in the locomotive, particularly at speeds below 70 mph.

The two acceleration curves, Fig. 2 in time, and Fig. 3 in distance, coincide exactly up to speeds of 16 mph and are so similar, up to speeds of 70 mph, that it is impractical to show them separately. A small further decrease in weight in locomotive *B* or the trailing cars, or a slight increase in horsepower, would make the performance the same over the entire speed range of the trains.

Fig. 4 while shown as a single curve is really two curves, giving the available drawbar pull per ton of train weight for each complete train. They fall so close together that the width of the line covers the difference. These small differences are apparent only during 100 per cent load-factor operation. Any schedule of the *A* train, which is operated at or under 90 per cent load factor, would probably be duplicated by the *B* train operating at a slightly higher load factor than the *A* unit.

RELATIVE OPERATING COSTS

Table 1 shows some of the economies which may be realized in the operation of a light road locomotive. The fuel saved per year, on the basis of a 60 per cent load factor and 6000 hr a year operation amounts to 145,000 gal. With a lubricating-oil consumption of 3000 hp-hr per gal under like operation, a saving of 900 gal per year could be expected.

The first cost of the light locomotive is difficult to estimate until more detailed specifications and designs are completed. The notations in Table 1 relating to first cost are estimates only

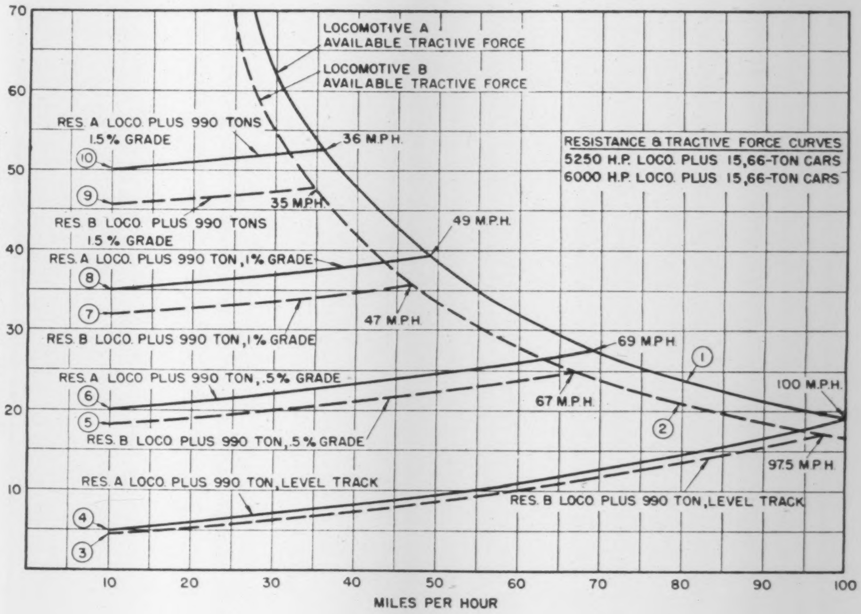

FIG. 1 RESISTANCE AND TRACTIVE-FORCE CURVES
(Locomotive *A*, 6000 hp; locomotive *B*, 5250 hp; each plus fifteen 66-ton cars.)

Contributed by the Railroad Division and presented at the Annual Meeting, New York, N. Y., Nov. 30–Dec. 4, 1942, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

TABLE 1 CHARACTERISTICS OF DIESEL ROAD LOCOMOTIVES

	Locomotive *A*	Locomotive *B*	Weight saved, lb
Weight of locomotive, lb	1035000	760000	275000
Horsepower of locomotive	6000	5250	..
Number of axles	18	14	..
Weight per axle, lb	57500	54300	..
Number of engine cylinders	36	120 or 128	..
Weight of Diesel engines, lb	198000	52500	145500
Weight of Diesel engines, lb per hp	33	10	..
Weight of electrical equipment, lb	190000	166000	24000
Weight of electrical equipment, lb per hp	31.7	31.7	..
Weight of mechanical equipment, lb	600000	540500	59500
Weight of mechanical equipment, lb per hp	100	102.75[a]	..
Weight of lubricating oil, fuel, and water, lb	47000	41000	6000
Weight saved by eliminating one 4-wheel truck			26000
Weight saved by use of aluminum tanks for oil, fuel, and water			5250
Weight saved by use of aluminum for locomotive cab			8750
Weight saved by use of aluminum in Diesel engine			34125
Total weight saved by use of aluminum			48125

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[a] This increase is to make allowance for parts which are common to both locomotives and cannot be reduced in weight on the basis of horsepower, such as car-heating equipment and controls.

	Loco. *A* plus 15–66 ton cars, mph	Loco. *B* plus 15–66 ton cars, mph
Maximum speed, level track	100	97.5
Maximum speed, 0.5 per cent grade	69	67
Maximum speed, 1 per cent grade	49	47

Fuel oil saved per year.....145000 gal
Lubricating oil saved per year.....900 gal

	Locomotive *A*	Locomotive *B*
Cost of locomotive at $100 per hp	$600000	$525000
Cost of saving 48125 lb at 40 cents per lb	...	19250
	$600000	$544250

but can be rationalized for the purpose intended. They are based on the assumption that the cost of locomotive *A* bears a definite relation to its horsepower and that locomotive *B* costs will be in close agreement, except where materials used to save weight cost more than the materials replaced. In this analysis some 48,000 lb were saved by replacing materials now used with aluminum. At a cost of 40 cents per lb saved, which is a very conservative figure, the weight reduction would add $19,200 to the cost of the *B* locomotive. The total cost of locomotive *A* is about 10 per cent higher than that of the *B* unit.

Because no unusual engineering has been proposed for locomotive *B*, maintenance cost should be no higher than existing equipment and might well be lower because of the fewer axles and lighter axle loads. The use of an increased number of engines should lead to maintenance procedure that could easily result in lower costs and greater availability.

If this analysis is based on sound fact and reasoning, the economic advantage of the proposed locomotive is established. Both the performance and economic characteristics are accomplished by the reduction in the weight of the proposed locomotive and ways and means to produce that result must be established.

Many developments in the Diesel industry have been made in the past few years which have contributed to more compact and lighter engine designs. Engines of 10 lb per hp are available at conservative rating and are as long-lived and reliable as their earlier predecessors. Three major developments are responsible, each contributing to the greater compactness and lighter weight. These developments, which will be discussed briefly, are as follows:

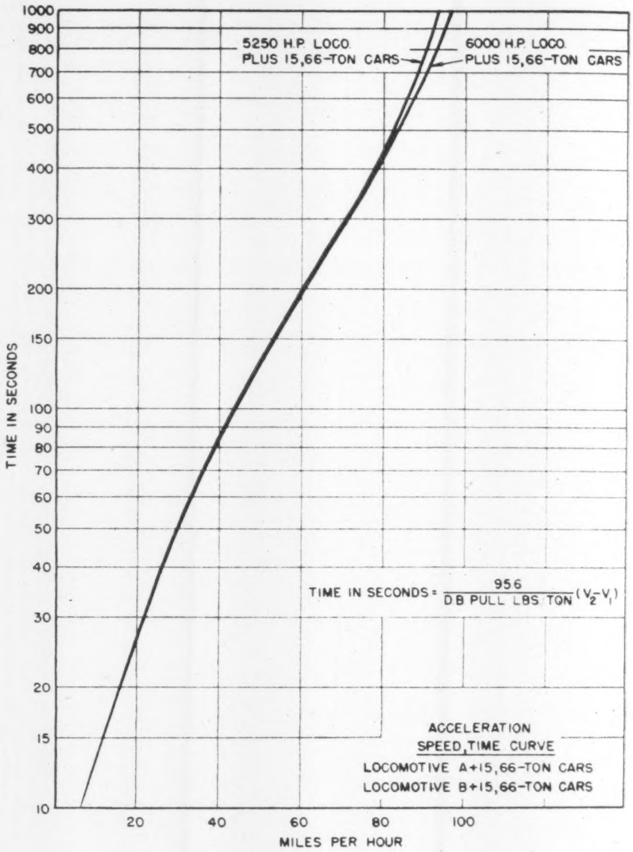


FIG. 2 ACCELERATION SPEED-TIME CURVE

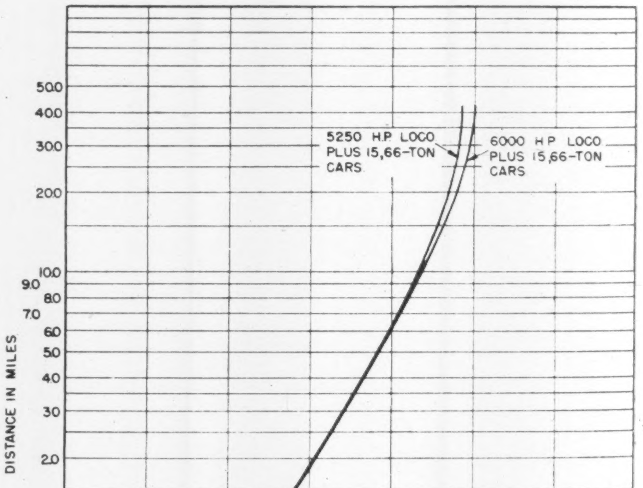


FIG. 3 ACCELERATION SPEED-DISTANCE CURVE

TABLE 2 FORMULAS USED IN COMPARISON OF DIESEL ROAD LOCOMOTIVES

		10	20	30	40	50	60	70	80	90	100
	A Locomotive + 15–66 Ton Cars										
1	Resistance, locomotive 1	480	616	814	1066	1380	1750	2166	2650	3190	3782
2	Resistance, locomotive 2	995	1140	1335	1550	1742	2022	2282	2560	2860	3160
3	Resistance, cars	3380	3870	4470	5200	6050	7020	8120	9320	10680	12120
4	Total resistance	4855	5626	6619	7816	9172	10792	12568	14530	16730	19062
5	Available TE	191000	95500	63750	47800	38300	31800	27300	23900	21200	19100
6	Net available TE	186145	89874	57131	39984	29128	21008	14732	9370	4470	38
7	Available TE per ton	123.4	59.0	38.0	26.5	19.3	14.0	9.8	6.22	2.97	...
	B Locomotive + 15–66 Ton Cars										
8	Resistance, locomotive 1	608	761	970	1235	1560	1945	2385	2880	3440	4040
9	Resistance, locomotive 2	462	548	645	745	855	970	1100	1235	1380	1530
10	Resistance, cars	3380	3870	4470	5200	6050	7020	8120	9320	10680	12120
11	Total resistance	4450	5179	6085	7180	8465	9935	11605	13435	15500	17690
12	Available TE	167000	83500	55600	41750	33400	27850	23850	20850	18600	16700
13	Net available TE	162550	78321	49515	34570	24935	17915	12245	7415	3100	...
14	Available TE per ton	118.8	57.2	36.2	25.2	18.2	13.1	8.95	5.42	2.26	...

Lines 1 and 8: $\text{Resistance, lb} = 1.3 + \frac{29}{W} + 0.03V + \frac{0.0024 \times 120V^2}{WN}$

Lines 2 and 9: $\text{Resistance, lb} = 1.3 + \frac{29}{W} + 0.045V + \frac{0.00034 \times 120V^2}{WN}$

Lines 3 and 10: $\text{Resistance, lb} = 1.3 + \frac{29}{W} + 0.03V + \frac{0.00034 \times 120V^2}{WN}$

Lines 5 and 12: $\text{Tractive effort, lb} = \frac{0.85 \times \text{hp} \times 375}{\text{mph}}$

Lines 6 and 13: Available tractive effort, lb = tractive effort − total resistance

Lines 7 and 14: Available tractive effort per ton = available tractive effort ÷ total train weight

1 The practicability of small cylinder sizes, resulting from advances in injection equipment.

2 Supercharging, allowing for higher safe engine rating.

3 Materials relatively new in Diesel construction.

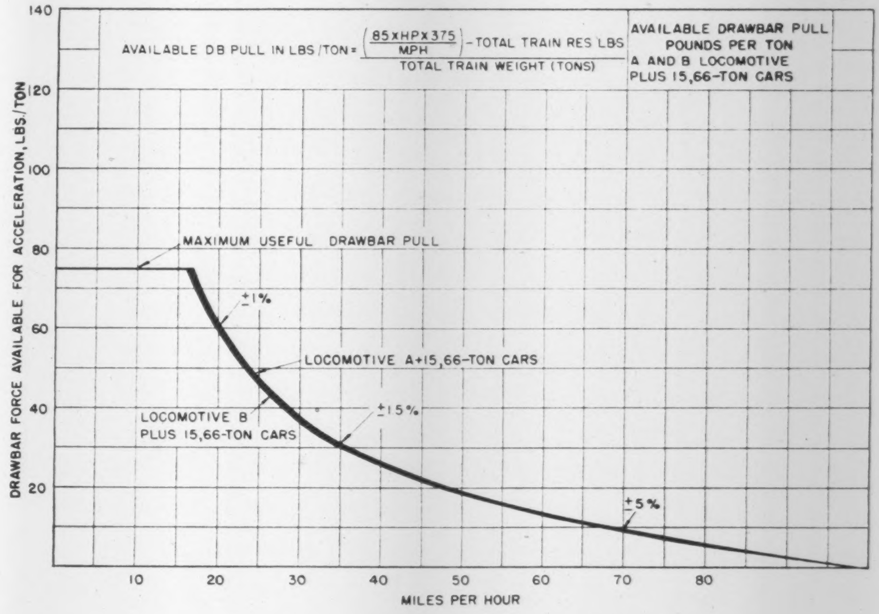


FIG. 4 AVAILABLE DRAWBAR PULL

EFFECT OF REDUCING CYLINDER SIZE

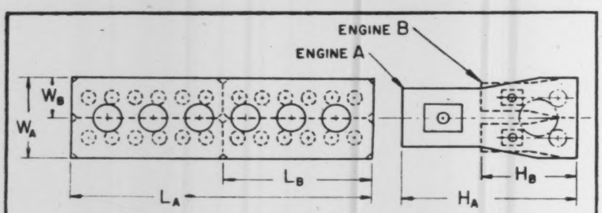
The combustion characteristics of Diesel engines are easier to control in large cylinder sizes because of the greater distances available for fuel penetration and larger quantities of fuel handled per cycle. Developments in injection equipment have made possible excellent combustion characteristics in small cylinders without the necessity of providing precombustion chambers which are prevalent in automotive-engine designs.

Engine dimensions for any given standard of design vary directly with the bore. In other words, the over-all lineal dimensions are reduced directly with the bore. Fig. 5 shows these relations in a comparison between engines with bores in the ratio of 2 to 1. Specifically stated, a single 1000-hp engine will weigh twice as much as four 250-hp engines having a bore $1/2$ that of the large engine. The space occupied by the four smaller engines will be one half that of the single large unit. These reductions have been made without change in the engine-rating materials of constructions or design standards, such as unit bearing pressures, cylinder centers, and bore-stroke ratios which are the major factors contributing to reliability and long engine life.

Supercharging has increased engine ratings materially and has also made small cylinder size more practical because of the larger quantities of fuel supplied per cycle. Increases in both piston speed and mean effective pressure become mechanical and thermal problems rather than volumetric problems which limit the output of naturally aspirated engines. Changes in engine rating have a direct influence on specific engine weight and specific compactness. An increase in both mean effective pressure and piston speed of 18 per cent result in weight and space saving in the order of 40 per cent.

Many, if not all, of the thermal problems in an internal-combustion engine are a function of waste heat to be dissipated per cycle per square inch of combustion-chamber area which includes pistons, cylinder head, valves, and cylinder liner. This heat load becomes a function of cylinder diameter. The small engine in the comparison, shown in Fig. 5, will have $1/2$ the specific heat load of the large engine. This provides a large factor of safety if higher mean effective pressures are contemplated and will not become the limiting factor in development in this direction within the range of near future probabilities.

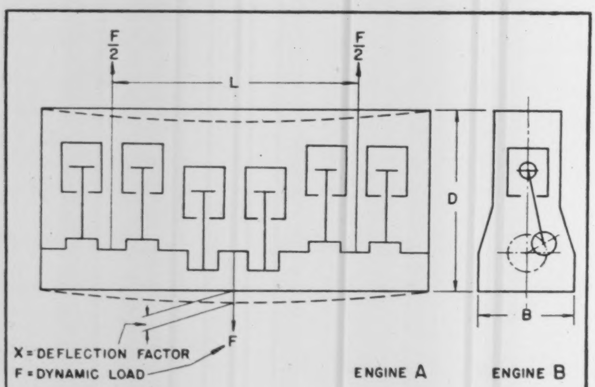
Analysis of the dynamic loading, which determines many of the bearing loads, shows that it is a function of the square of the cylinder diameter. In the comparison in Fig. 6 is shown a ratio of 1 to 4 in favor of the small engine. Bearing areas are



	ENGINE A	ENGINE B	COMBINED SMALL ENGINES
NO. OF CYLINDERS	6	6	24
HORSE POWER	4	1	4
BORE	2	1	1
STROKE	2	1	1
R.P.M.	1	2	2
PISTON SPEED	1	1	1
MEAN EFFECTIVE PRESSURE	1	1	1
COMPACTNESS FACTOR	8	1	4
WEIGHT FACTOR	8	1	4

COMPACTNESS FACTOR = (CONSTANT) HWL
WEIGHT FACTOR = (CONSTANT)(COMPACTNESS FACTOR)

FIG. 5 COMPARISON OF ENGINES WITH BORES IN RATIO OF 2 TO 1



	ENGINE A	ENGINE B
BORE	2	1
R = STROKE	2	1
N = R.P.M.	1	2
W = WEIGHT OF MOVING PARTS	8	1
D = HEIGHT OF ENGINE	2	1
B = WIDTH OF ENGINE	2	1
L = DISTANCE BETWEEN BEARINGS	2	1
F = CONSTANT (WRN^2)	4	1
X = CONSTANT ($FL^3 \div BD^3$)	2	1

FIG. 6 DYNAMIC LOADING AND DEFLECTION COMPARISON

also in the same ratio, so that unit bearing pressures do not change in spite of the higher rotative speed of the small engine. The possibility of further small-engine development could well be in the direction of increased speed without fear of reaching an impractical or unsafe operating-speed range. It is the dynamic loading of an engine which dictates many of its dimensional characteristics, which in turn determine rigidity factors. Fig. 6 also shows a comparison of the rigidity between the same two engines previously discussed. The small engine is inherently twice as rigid as the large engine, other factors being the same.

The advantages of a small engine may be summarized as follows: Engine *B* compared with engine *A*, both having the same specific output, has:

1 One half the specific weight.
2 One half the specific bulk.
3 The same general volumetric characteristics.
4 One half the specific-heat load per cycle.
5 One fourth the dynamic load factor.
6 Twice the inherent rigidity.

The multiplicity of cylinders appears to be the one major difference which might detract from the advantages of small engines. This may well be counterbalanced by the greater basic reliability of the small engine by virtue of lower heat and dynamic load and deflection factors inherent in its small bore. The maintenance problem may well be simpler for the smaller engine because of the reduced weight of all of the engine parts allowing more ease in handling. There is also the possibility of replacing a complete engine generator unit in the event of failure or routine maintenance. A failure of one of the small engines would have far less influence on the locomotive performance than a complete failure of one large engine. Multiplicity of engine cylinders in other internal-combustion-engine applications has tended to increase reliability rather than otherwise.

IMPROVED CHARACTERISTICS FROM USE OF LIGHTER MATERIALS

The weight of an engine is a direct function of the specific weights of the materials used. Substituting lighter materials produces weight saving, unless the design factors have to be changed to such an extent that they nullify the difference in material weights.

Aluminum has been extensively used in internal-combustion engines for a wide variety of applications. Its characteristics do not, however, lend themselves to all of the parts going to make up a Diesel engine. Crankshafts, camshafts, valves, and cylinder liners are the major items which cannot be made in aluminum. These parts, plus other miscellaneous parts in the same category, however, account for about 25 per cent of the weight of an engine built of cast iron or steel. The cylinder block, crankcase, oil pan, cylinder heads, pistons, gears, gear covers, supercharger housing, manifolds, fuel-pump housings, pumps, governor housings, fuel filters, and air filters make up the other 75 per cent of the weight. They can and have all been successfully made in some suitable aluminum alloy. Weight savings from 30 to 70 per cent can be made, depending upon the function and design characteristics of the particular part. Much experience has shown that an average saving of 50 per cent can be made safely and without compromise to sound design practice. The net result on the total engine weight would be a reduction of $37^1/_2$ per cent.

The engines for locomotive *B*, described earlier in this paper, built of the same materials as engines in the *A* locomotive and with the same piston speed and mean effective pressure weigh 16.5 lb per hp. Built in aluminum, their weight would be 10.3 lb per hp. This weight so closely approaches the requirement for engine weight set up in Table 1 as to justify its use. Numerous other advantages of aluminum for Diesel engines, all contributing to low specific weight and smaller space requirements could be described but it is beyond the scope of this paper to discuss them. The is of aluminum for the parts proposed is fully justified by operating experience in other applications. They should be carefully engineered for this new application to insure a like satisfactory operating experience.

Referring again to Table 1, lines 14, 15, and 16, list a total of 40,000 lb to be saved in parts other than engines. A large part of this weight saving can be made by reducing the number of axles under the locomotive with no increase in load per axle. Locomotive *A* was built with 18 axles with a load of 57,500 lb per axle. Locomotive *B*, because of its reduced weight, could have 14 axles loaded to 54,250 lb per axle. Two of the four axles eliminated are included in the saving listed opposite the item "weight saved in mechanical equipment." The other two axles eliminated are listed on line 13, Table 1, as: "weight saved by eliminating one 4-wheel truck." The saving is 26,000 lb which is the estimated weight of this assembly less traction motors. This figure subtracted from the 40,000 lb listed leaves 14,000 lb to be saved in the cab, tanks, and electrical and mechanical equipment.

Tanks for lube oil, fuel, and engine-cooling water weigh,

(*Continued on page 359*)

DIESEL-LOCOMOTIVE PROGRESS *Under* WAR CONDITIONS

COMMENT BY P. A. McGEE[1] AND PAUL TURNER[2]

PROGRESS in the development and operation of Diesel motive power on our railroads can be best told by the numerous railroads employing this type of power, and an appropriate progress report can be compiled from the operating data available from these roads.

The Diesel locomotive, with its few years of development, has been very quickly standardized for both switching and main-line haulage. This standardization has recognized the flexibility which may be built into this type of power and the desirability of keeping down axle loads to suit general conditions. Its inherent efficiency practically precludes any revolutionary change in the now accepted standard designs.

These features, in themselves, make the Diesel locomotive, to whatever purpose applied, a very satisfactory tool under the stress of war conditions.

In all the services to which the Diesel locomotive may be applied, it uses a minumum of material for the work required and lends itself to maximum availability under adverse circumstances of fuel and other supplies.

There will naturally be metallurgical improvements in the development of the Diesel locomotive but even though it is a comparatively new type of motive power, the technical improvement to be expected will probably not be fundamental. The Diesel-locomotive application is then in the fortunate position of presenting merely an economic problem.

The immediate problem of the railroads today is to obtain power to meet the ever-increasing ton-miles offered for transportation, and whatever power is available must be employed for this purpose, regardless of the economy of the situation. In this respect, some of the advantages of Diesel over other power in the three types of locomotive service into which railway operation is usually divided might well be mentioned here.

In switching service, the Diesel locomotive offers a much easier machine to operate than the conventional steam switcher. Under extreme conditions, operators could continue to operate Diesel switchers for a longer period than conventional steam switchers. In fact, under extreme conditions of limited available manpower, a Diesel switcher in the majority of yard services, if suitable visibility is designed into the locomotive, might very well be operated by one man.

In the case of passenger service, Diesel locomotives readily lend themselves to high-speed service, with minimum wear and tear on the right of way. In the case of through runs over different railway systems, the standard Diesel passenger locomotive can perform a coast-to-coast service with a minimum of supervision over operating crews.

In freight service, the Diesel locomotive presents one standard machine which can be applied to all types of profiles under the variable weather conditions of the continent.

In both passenger and freight main-line services, the Diesel locomotive is preferred by the crews and offers the greatest comfort and ease in operation.

COMMENT BY G. F. WILES[3]

Modern Diesel-electric locomotives for switching, passenger, and freight services were developed principally during an economic depression period of several years' duration, by organizations with the resources to continue such development.

While this economic condition had many bad features in this particular field the conditions were ideal for the necessary development. The best engineering talent was free to follow this development exclusively the necessary materials were available without restriction, and skilled mechanics were also available. It was essential for any new locomotive offered to the railroads for service to be capable of operating at a lower cost for a given amount of work performed and have other operating advantages, so that the purchase of such units at that particular time could be justified. These necessities were a challenge to the designers.

Radical departures were made from past standards of design for Diesel engines, electrical equipment, underframes, superstructures, and trucks, use being made of modern materials and processes, especially electric welding.

Diesel engines deliver more horsepower per pound of weight. The electrical transmission and control equipment were designed especially for locomotive service. Underframes, superstructures, and trucks were developed which eliminated all surplus weight consistent with durability and safety. These developments were made with the co-operation of the railroads, and their requirements were fully considered. Where operating conditions permit and these locomotives have been used to their full availability, the expected performance and economies have been fulfilled. Under war conditions, engineering talent, skilled labor, and materials are being devoted to machines of war, the design and construction of which are being advanced and expedited by the experience gained in the railroad field.

During the present emergency, it is necessary to substitute materials for those not now available, extend the periods of renewal of all parts possible, and train many new mechanics so that the high availability which has been attained can be continued for the duration of the emergency.

Compared with some forms of motive power, the Diesel locomotive is comparatively new, and there are some parts which limit the power that can be developed and cause trouble. No doubt further improvements in this will be made.

The nature of the wearing parts of the Diesel engines and electrical driving gear is such as to make them adaptable to progressive maintenance, which permits all operations other than major overhauling to be performed in short periods. This accounts largely for the high availability attained.

There is no question but that some of the substitutions and practices developed during this period will be continued. The experience gained from the design, development, use, and maintenance of these machines will result in a new era of Diesel-locomotive development after the war.

COMMENT BY MAX ESSL[4]

Early in our active participation in the war, the War Production Board requested The Baldwin Locomotive Works to produce only standard-design 120-ton, 1000-hp Diesel switchers. Only such design changes may be made which will not affect

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[1] Electromotive Division, General Motors Corporation, New York, N. Y.

[2] Eastern Regional Manager, Electromotive Division, General Motors Corporation, New York, N. Y.

Contributed by the Oil and Gas Power and Railroad Divisions and presented at the Annual Meeting, New York, N. Y., Nov. 30–Dec. 4, 1942, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

[3] Supervisor, Diesel Electric Locomotive Operations, Baltimore & Ohio Railroad, Baltimore, Md.

[4] Chief Consulting Engineer, The Baldwin Locomotive Works, Philadelphia, Pa.

production and such as are necessitated by material substitution. Production curves are shown in Fig. 1.

Although these limitations do not permit of any major changes, considerable progress has been achieved. A brief outline of these improvements shows the following:

1 Production has increased as a result of concentrating on one size of locomotive, standard design for all customers, and increasing manufacturing facilities. The latter is partly due to the fact that the same type of engine is used for locomotives and Navy application.

2 Improvement in performance:

(*a*) The Diesel engine has been improved due to several refinements which were developed in our testing laboratories. This resulted in lowering the fuel consumption to 0.365 lb per bhp-hr at full load and full speed. Lower fuel consumption and improved valve and fuel timing have brought about increased overload capacity or reserve power of the Diesel engine.

(*b*) The temperature control of the cooling system has been materially improved by the combination of larger-capacity radiators, pneumatically controlled shutters, and the addition of a cooling-fan clutch.

(*c*) The electrical transmission has been altered so that maximum locomotive speed can be obtained without transition. The electrical hookup remains series parallel throughout the locomotive speed range.

(*d*) The over-all electrical transmission efficiency has been improved by means of an automatic load-control device. This assures full-load engine and generator output regardless of temperature of the generator (see Fig. 2).

3 Increased reliability of the locomotive has been achieved by numerous refinements. Such improvements are due to automatic hydraulic-valve-tappet adjusters, simplified piping, better machine operation resulting from improved tooling, and many other improvements too numerous to mention.

4 Easier maintenance has been assured by many modifications, resulting in better accessibility and reduction in time required for servicing.

5 Material substitutions, as required by the national emergency, have in no case resulted in an inferior product. Although all rubber, tin, practically all nickel, chromium, and most of the copper have been eliminated, no trouble has been experienced because of these changes. The reason for this is the fact that the substitute steels, particularly those of manganese-molybdenum type, have very excellent qualities.

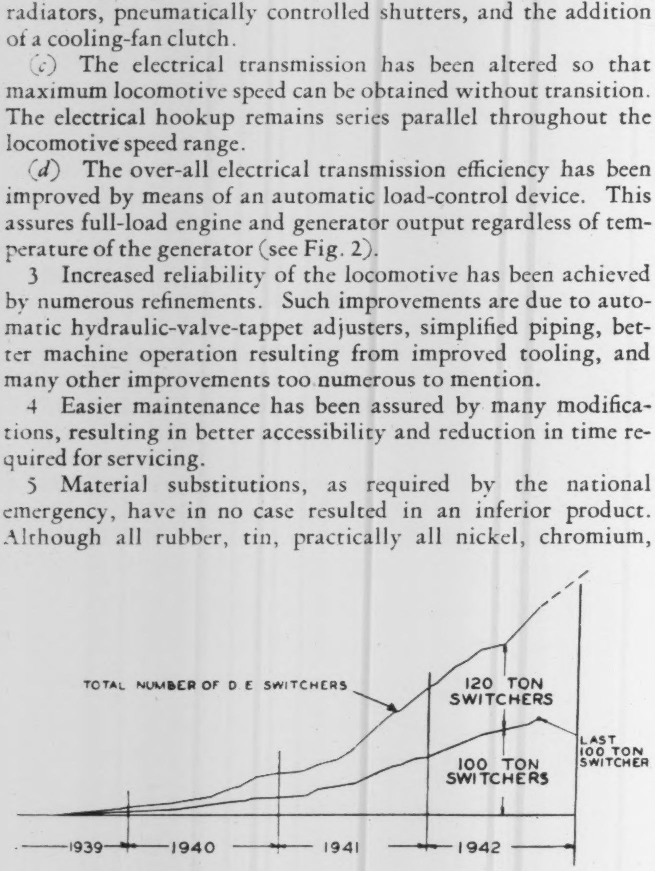

FIG. 1 PRODUCTION TREND, BALDWIN DIESEL-ELECTRIC SWITCHER LOCOMOTIVE

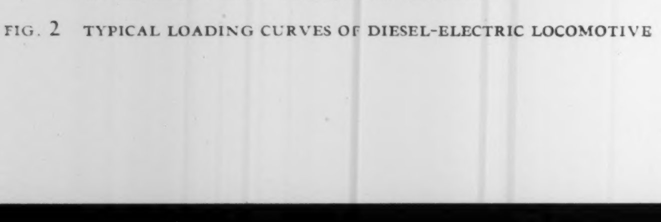

FIG. 2 TYPICAL LOADING CURVES OF DIESEL-ELECTRIC LOCOMOTIVE

To summarize, although the national emergency has frozen basic designs, it has been possible to improve considerably the over-all performance, efficiency, and maintenance of Baldwin Diesel locomotives and pass on these improvements to the railroads, in the form of increased economy of operation. This has been accomplished although material substitutions have been numerous. Production has been considerably increased, not to a small degree because of the better over-all performance of the switchers due to improvements mentioned, but because better performance means less time out of service and fewer spare-parts requirements which, in turn, means that more new units can be manufactured.

COMMENT BY W. S. H. HAMILTON[5]

On the New York Central we have specialized in the application of 600-hp, 110-ton Diesel-electric-switching locomotives for the majority of the operations to which Diesel-electric locomotives have been applied. This particular size of locomotive matches very closely the weight on drivers and starting tractive effort of our class U, 8-wheel steam switching locomotives. While the latter type has approximately 3 times the maximum horsepower of the former, this is not developed until speeds of 25 to 30 mph are reached, which are greater than those normally used in switching service. The 600-hp, 110-ton Diesel-electric locomotive develops a greater drawbar pull up to 2.5 mph and, although it has only approximately 60 per cent of the weight of the steam locomotive including tender for braking, actual experience has shown that it will successfully do the work of these steam locomotives in flat-yard switching service, and occasionally in transfer service where sufficient time is available to permit lower speeds than those of the steam locomotives to be used.

The first point at which the replacement of these class U locomotives by 110-ton Diesel-electric locomotives was made was at Buffalo where there were a number of locations requiring operation of switching locomotives 3 tricks a day or 21 tricks per week. Experience in that operation indicates that 29 of these Diesel-electric locomotives would do the work formerly requiring 40 steam locomotives, 28 of which were class U. The steam locomotives released were transferred to other points on the system, permitting the retirement of other locomotives giving unsatisfactory service because of age or obsolescence. The results at Buffalo led to an even larger installation at Detroit where thirty 110-ton and four 128-ton Diesel-electric locomotives were placed in service with equally satisfactory results.

The studies in preparation for these installations and data on their subsequent performance have indicated that, to secure the necessary economies under present-day conditions, these Diesel-electric locomotives should be installed at locations where they will be in service at least 18 tricks per week, and that locations requiring a lesser number of tricks per week will be more economically handled by steam locomotives.

The increased traffic due to the war caused an increased demand for switching locomotives, particularly those of the class U type at many points on our system, and the desire to secure quickly as many of these as possible, as well as to secure the economies resulting from operation of Diesel-electric locomotives at points where they could be intensively utilized, led to our placing an order in the early part of 1942 for those Diesel-electric locomotives: Thirty 600-hp, 110-ton switching locomotives; two 4000-hp road passenger locomotives; in addition to seven 380-hp, 70-ton switching locomotives already ordered.

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[5] Equipment Electrical Engineer, New York Central System, New York, N. Y.

Conditions arising from the war effort required us to change the order for the two road passenger locomotives to two 5400-hp road freight locomotives, the delivery of which is uncertain at present. Most of the 110-ton switching locomotives on order have had to be furnished at 100 tons which is regretted as this considerably reduces the capacity of the locomotives in flat yard switching service. It will also interfere to a certain extent with interchange of locomotives in years to come. The locomotives as received are placed in service at locations where they will release the maximum number of class U locomotives for service at other points, some of which require their use in transfer service.

The seven 70-ton switching locomotives are being placed in service generally at locations where bridge and other structures reduce the allowable wheel loading to this weight, and where in general the service is light, as at isolated yards and terminals. They cannot move as heavy cuts of cars as can the 100- or 110-ton locomotives, but they give a good account of themselves.

Also, there are locations where the axle loading is not limiting but where such light switching locomotives, as a result of their lower first cost, can be utilized to good advantage, due to the service requiring a switching locomotive to be on duty, but not requiring the handling of heavy cuts of cars. Some of these seven locomotives will be applied to such locations, and their performance will be observed with interest.

It is our intention to continue with studies of the application of these 600-hp, 110-ton locomotives and the 380-hp, 70-ton locomotives at those locations where we believe the necessary performance can be obtained. We will thus know which locations should be given serious consideration for application of additional Diesel-electric locomotives as they become available.

It may be of interest to know that we now have in service on the New York Central System ninety-nine 600-hp locomotives of 100 and 110 tons weight, three of 380 hp, 70 tons weight, and forty-three locomotives of various other classes, most of which weigh approximately 128 tons on drivers. This makes a grand total of 145 locomotives which we believe is the largest number of Diesel-electric switching locomotives in service on any single railroad system in the United States.

Comment by B. S. Cain[6]

From a design standpoint, there is little to report on Diesel-electric-locomotive progress under war conditions, because government decree at the start of the war practically limited new production for the duration to the existing standard sizes and types best suited to wartime needs.

From an application and manufacturing standpoint, however, the war has brought progress, particularly in the small-size and the all-purpose locomotive. Today, with railroads handling an increasing amount of record tonnage, there is a critical shortage of motive power and the demand for new locomotives far exceeds the available supply. Therefore, the emphasis is on standardization, to obtain greatest output from the limited manufacturing capacity and, on application, to make the most efficient use of the limited materials available.

There has been a tremendous expansion in the use of small Diesel-electric locomotives in industrial service. The standard sizes, produced by the hundreds, range in sizes from 25-ton 150-hp to 80-ton 500-hp, all about 6 to 7 hp per ton. These locomotives have plenty of power for industrial switching and can be worked three shifts a day. Moreover, they use a high-speed Diesel engine that is produced in such quantities as to leave a surplus over the great demand for implements of war. This surplus is available for locomotive use. The economy in labor and critical materials in these small Diesel electrics is well indicated by their price of roughly 25 to 33 cents per lb.

For light railroad service, the 44-ton, 380-hp Diesel-electric

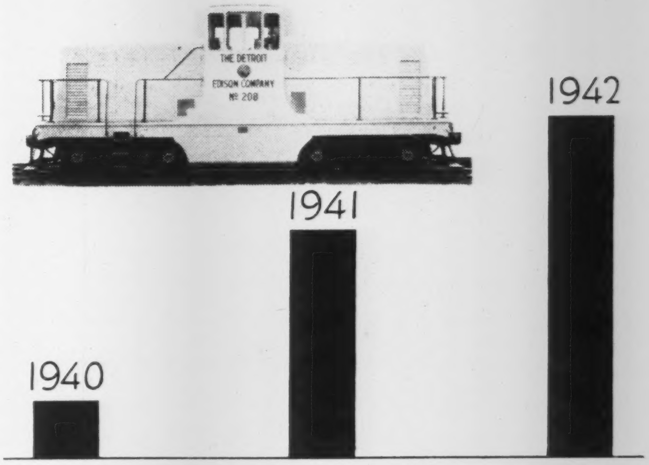

FIG. 3 SHIPMENTS OF STANDARD INDUSTRIAL DIESEL SWITCHERS FOR THE YEARS 1940–1942
(Locomotive shown is typical 65-ton, 400-hp switcher.)

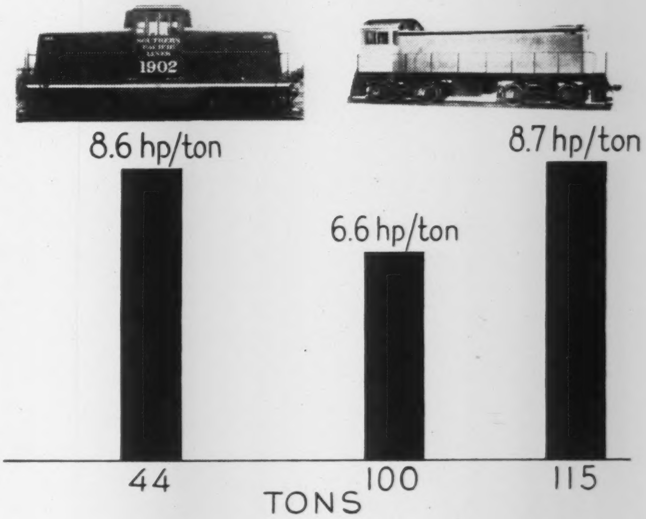

FIG. 4 STANDARD RAILROAD SWITCHERS
(Upper left, 44-ton, 380-hp locomotive; upper right, 100-ton, 660-hp, and 115-ton, 1000-hp locomotives.)

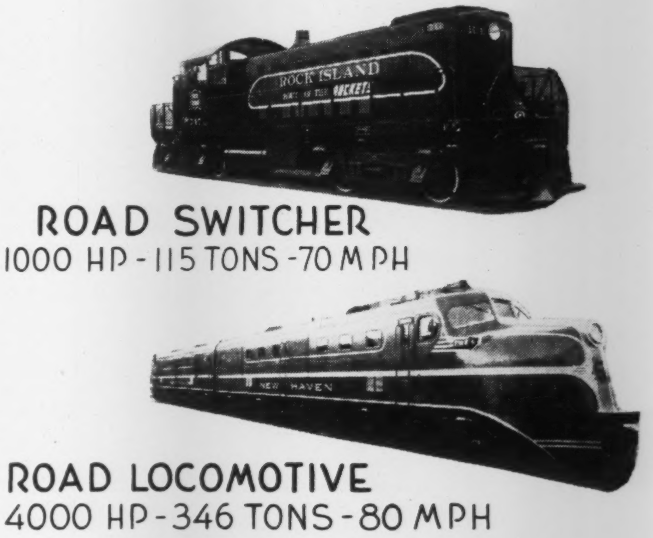

FIG. 5 STANDARD DIESEL ROAD LOCOMOTIVES
(Upper, 1000-hp road switcher for Rock Island. Lower, 4000-hp passenger and freight for New York, New Haven, and Hartford.)

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[6] Assistant Engineer, Locomotive Division, General Electric Company, Erie, Pa. Mem. A.S.M.E.

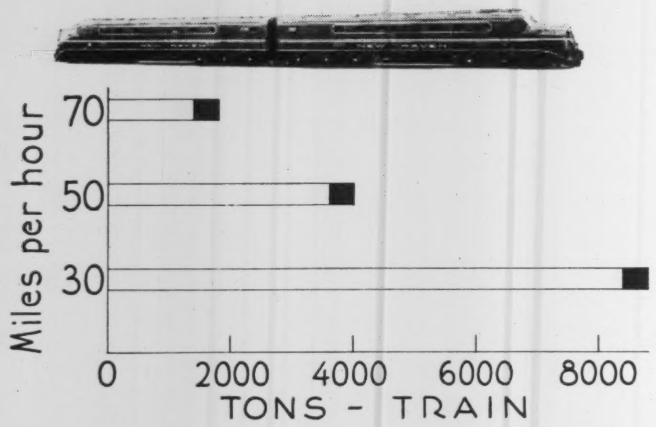

FIG. 6 TONNAGE WHICH CAN BE HAULED ON LEVEL TANGENT TRACK BY 4000-HP STANDARD DIESEL-ELECTRIC LOCOMOTIVE, GEARED FOR 80 MPH TOP SPEED

locomotive ($8^{1}/_{2}$ hp per ton) has proved itself most useful for both switching and light road service. Its high availability, 95 per cent, makes for maximum utilization of vital materials. These Diesels can often be put in three-shift-a-day operation, thus releasing more than the same number of steamers for service at other locations. In the past 2 years, some thirty different railroads have put more than 100 Diesel electrics, under 100 tons, in service.

For heavier service, there are two standard switchers, 660 hp and 1000 hp, with 100 and 115 tons on drivers. The 1000 hp supercharged unit can maintain its acceleration up to higher speeds and is normally placed at bottlenecks to speed up yard movements. Their value in the present crisis is evidenced by the fact that future production of Diesel-electric switching locomotives over 100 tons for dometic use has been limited principally to this size.

Diesel locomotives for high-speed streamliners are no longer being manufactured and schedules of those in service are being lengthened, but the reliability, performance, and economy of the road Diesel has been recognized and this locomotive has already made a place for itself. The 1000-hp supercharged road switcher has a maximum speed of 70 mph and a tonnage rating of 700 to 1700 tons per unit in freight service, depending upon the profile. The 2000-hp unit, geared for 80 or 90 mph top speed is well adapted for fast passenger service, alternating with freight. Some of these units handle over 2000 tons each in freight service. Connecting two or three of these, thus providing up to 6000 hp, constitutes an important unit of motive power.

In these days of war, there is another class of service to be considered, and that is foreign service for the War Department. Such locomotives must often be suitable for operation in almost any part of the world, they must be capable of either road or switching service, and are usually limited to an axle load of 20 long tons or less. Because road service often requires considerable weight and horsepower, these locomotives should be fitted with multiple-unit control, so that two or three can operate together when the draft gear can take the full output. The 44-ton locomotive, referred to previously, is well adapted for such requirements, having only 10 long tons per axle and a maximum speed of 35 mph or 56 kph.

The 660- or 1000-hp locomotives can be equipped with two 6-wheel trucks and then weigh approximately 120 short tons total or 18 long tons per axle. Such a locomotive can operate up to 60 mph or 96 kph and is well suited for foreign road and transfer work.

No attempt has been made to cover special designs or applications, since the emphasis today is on standard designs and quantity production. This does not mean that design progress has stopped. The requirements of war force the intensive development of power plants with greater power in less space with less weight, designed for mass production. The locomotive builders are ready to adapt these developments to railroad use and all indications are that the next stage in Diesel-locomotive development will far surpass anything yet seen.

Comment by P. H. Hatch[7]

In wartime, the movement of freight becomes of primary importance and the railroads of the country, as the backbone of the freight-transporation system, assume the title role. As experience in the first world war indicated, poor terminal conditions can set the whole program at naught and nullify the benefits of getting freight trains over the road quickly between terminals.

In this war, the Diesel switcher constitutes a new and successful tool in handling and expediting terminal movements. It has the ability literally to stay on the job for weeks at a time. It has high fuel economy and therefore conserves fuel. It is able to exert full horsepower at switching speeds and, as a result, give maximum performance where it is most useful. Its maintenance cost is low, and the facilities required for its servicing are simple. It lends itself ideally to standard construction and unit replacement of parts. It is easier on the operators, provides greatly improved visibility and does not impair operations with clouds of steam in cold weather. In short, its properties and characteristics are such that for switching service it eliminates terminal motive power as a problem.

At about the time this country entered the war, there were in service or on order 1544 Diesel switching locomotives, the great majority of these being built and placed in service in the last 10 years. The rapidity of this growth is another indication of the basic soundness of this type of motive power for terminal operation.

On August 5, 1931, the New Haven Railroad placed in service its first Diesel switcher which incidentally was the first 100-ton, 600-hp Diesel switcher built by The American Locomotive Company. It was powered by a McIntosh & Seymour 6-cylinder $12^{1}/_{2}$-in. × 13-in. Diesel engine. Today, this same locomotive is operating side by side with other similar but more modern locomotives in the Diesel switcher pool at Boston.

In 1936, ten 100-ton, 600-hp Diesel switchers were placed in service, these locomotives having double-reduction-gear traction motors, battery charging at idling only, and other innovations. Five of these were powered by Cooper-Bessemer type GN-8 8-cylinder $10^{1}/_{2}$-in. × 12-in. engines and five by Ingersoll-Rand Type C 8-cylinder 10-in. × 12-in. engines, the Diesel engines and locomotives being co-ordinated to the extent that either type of engine can be used in any locomotive.

The original locomotive and these ten were the pioneers on the railroad and have been followed by additional orders, until today the New Haven has in service a total of 58 Diesel switchers, of which 51 are nominal 100-ton, 600-hp single-power-plant locomotives, and seven are 44-ton, 380-hp twin-power-plant locomotives. Except for the ten 100-ton, 600-hp locomotives of 1936 described, all Diesel switchers of this size are Alco type. The seven 44-ton switchers were built by General Electric Company and were powered by Caterpillar D-17000 8-cylinder Vee $5^{3}/_{4}$-in. × 8-in. locomotive-type Diesel engines.

The 100-ton, 600-hp locomotives are for the most part assigned to the larger terminals or to important switching areas where 24-hr daily service in passenger or freight switching predominates; the smaller locomotives are used at outlying points where the duty is relatively light and the hours of service less.

That the Diesel-electric switching locomotive is fitting into the New Haven picture and is furthering the war effort can be judged by the fact that 20 more 100-ton, 600-hp Diesel switchers are currently on order.

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[7] Assistant Mechanical Engineer, New York, New Haven, and Hartford Railroad, New Haven, Conn.

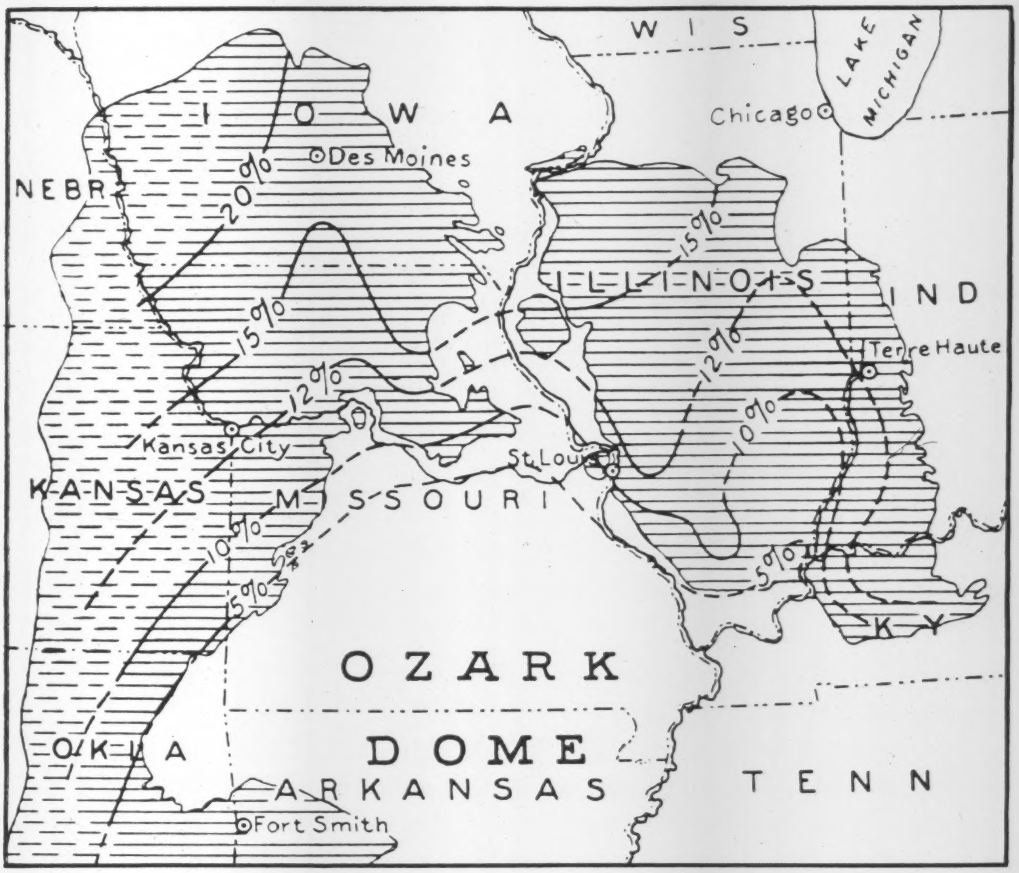

FIG. 1 CAMPBELL'S LINES OF EQUAL MOISTURE VALUES

IOWA COALS *in the* NATIONAL EMERGENCY

By H. L. OLIN

PROFESSOR OF CHEMICAL ENGINEERING, STATE UNIVERSITY OF IOWA

THE arbitrary lines laid down in drawing political boundaries are obviously inadequate for making the distinctions in quality of natural products found within a given area. The waters of the misty Paleozoic swamps of the Pennsylvanian period rippled over the peaty ooze unhampered by rivers and mountain chains that came into being thousands of mileniums later or by state lines of still more recent origin. And so in the field to be discussed in this paper will be included the two oldest of the Illinois seams, Nos. 1 and 2, closely related in quality to those of Iowa.

The Iowa coal fields comprise the western margins of the area known in geological parlance as the Interior Province, a region extending from the eastern borders of Kansas and Nebraska on the west to the western fringes of Kentucky and Indiana on the east. Much of this original structure, within the limits of present-day Iowa, was eroded in post-Paleozoic time by the Mississippi system, and with it vanished unmeasured riches in the form of the coal it contained. In any event, the best and the thickest of the coal seams that have survived lie in the eastern region of this province, particularly Nos. 5 and 6 of Illinois, and Nos. 4 and 5 of Indiana, which occupy what seems to have been the central portion of the great Pennsylvanian basin.

NATURE'S PROCESS OF PUTTING QUALITY INTO COAL

For purposes of comparison, let us note the chief merits of these latter coals, or rather the natural advantages upon which these merits are based. In addition to the great thickness of some of these seams (No. 6 in Franklin County, Illinois, in places, reaches 15 ft), and their widespread continuity, which are almost invariably associated with mineral purity or freedom from base rock, these coals were profoundly affected in their southern reaches by the diastrophism of the Ozark region, that is, by the upheaval and folding of the mountains by forces which compressed the coal in the seams near the center of dis-

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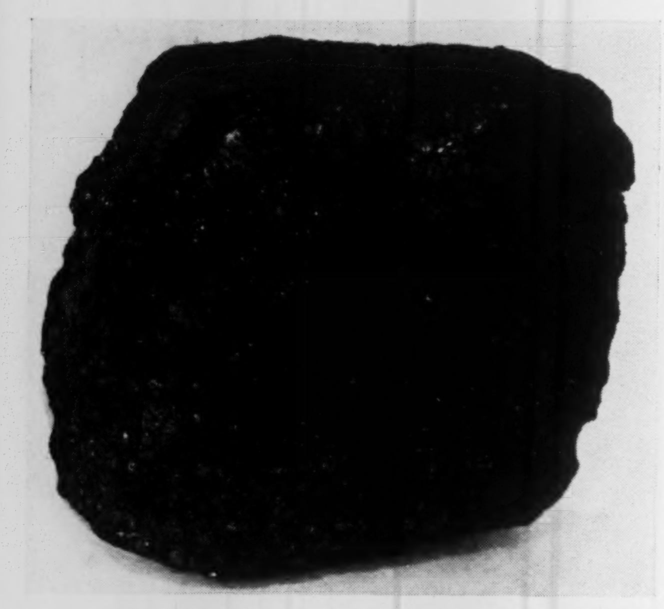

FIG. 2 ARKANSAS "SEMIANTHRACITE"

turbance to fuels resembling semianthracite, Fig. 2, but which only to a lesser degree hardened and chemically altered others along a wide radius. This is clearly shown by the results of Campbell's work plotted in Fig. 1 obtained from studies of mine-moisture contents of coals sampled over a large area. Thus it appears that mine moisture and with it certain chemical and physical properties, affecting the storability and other characteristics of coal, vary as some function of the distance from the active center. Moisture contents of the fuels from the self-styled "quality circle" of southern Illinois, of Indiana, and Kentucky range between 5 and 10 per cent; those of north and central Illinois and of Iowa lie beyond the reach of the Vulcanian arm and having missed the natural processing and refining of the more southerly coals they carry moisture values of 12 to 20 per cent. And so in a word, because the seams are thinner and smaller, costs of mining and preparation are higher and, because they were laid down in areas less favorable to natural coal-formation processes, they suffer somewhat in quality comparison with others in this general region.

In this estimate of the capacity of the coals of Iowa to meet the needs of a national emergency, we must clearly mark the implications of that emergency. Does it increase the demand for fuel? Does it to a certain extent block the normal channels of fuel flow? Does it increase the need for storage beyond the usual short periods in winter? Is the general coal-price level to be materially raised? Are the restrictions and regulations of the National Bituminous Coal Act to be maintained as usual? All these questions and more are relevant and material in reaching a conclusion, and we shall probably be safe in assuming affirmative answers to all of them.

PRODUCTION EXPANSION POSSIBILITIES

There is no reason to doubt that, under stress of increased demands for fuel in the Middle West or of possible freight embargoes on Appalachian coals, the production in Iowa could be greatly expanded. While the annual production fell in 1941 to an all-time low of little more than three million tons, the grand average for the last 50 years is more than twice that figure and, during the war years of 1917 and 1918, it went up to well over nine millions. Many of the seams to be sure have been worked out, but other surveyed reserves, both strip and deep, are awaiting only more favorable conditions for their opening. But it is the immutable law of economics as well as of animate life that in a competitive system, hard times strike down first the small and the weak. And so it is that in the last two decades the rise of the automobile and petroleum industries, the fading out of the short railroad haul, and regulatory legislation not always rigidly impartial, ills or influences to which the industry as a whole has been subject, have affected the Iowa producer out of balanced proportion and for reasons in nowise connected with his absolute ability to produce.

Under wartime conditions, however, the demands on a fuel are less dependent upon the normal economic equilibrium that regulates its production and distribution and more upon its inherent quality and adaptability to emergency conditions. Therefore, it is upon matters as thermal values, storability, friability, ash fusion, coking properties, and the like, that this discussion must center. The comments that follow are based upon long personal experience with Iowa coals in the field, in the laboratory, and in close association with engineers and with power-plant operators who have used them and who have come to recognize their virtues as well as their faults.

LACK OF CLEANING EQUIPMENT RESPONSIBLE FOR LOW QUALITY

From the standpoint of mere thermal values, there is little valid criticism to be directed against well-prepared Iowa coals, nor do they suffer in comparison with those of equal ash content from north and central Illinois, since all are of the same geological age and moisture values are approximately equal. In the author's experience in directing the sampling and testing of nearly ten thousand carloads of Midwest coal, most of it from Iowa, he has had ample opportunity to note the high quality that Iowa producers can put out on occasion when good mine-working conditions are joined with a conscientious purpose to maintain high standards. But we must face the bald fact that in Iowa alone of all the coal-producing states of the Midwest at least, there is today no provision for gravity cleaning or washing by either wet or dry methods, and so Iowa coals lack that uniformity of quality that we associate with mechanically cleaned fuels. The reasons for this situation are many and complex, and we need not review them here and now, except to remark that, while most of them are economic in nature, some are apparently only psychological. In a comparable situation, conditions in northern Illinois are quite as bad; only recently a shipment from a west Illinois mine delivered to an Iowa consumer tested less than 8000 Btu per lb.

The quality of steam coal, or screenings particularly, is variable and often unsatisfactory not only because it contains the fine undercuttings that may include floor rock, but because the laminar deposits in the cleavage planes, consisting of calcite or gypsum, are easily detached on handling and gravitate to this fraction (Fig. 3). But it must be noted that quality is subject to definite control even without mechanical purification. Crushed run-of-mine is measurably superior to straight screenings. By crushing the screen oversizes to steam coal, an even better product may be obtained to meet more exacting specifications of special war industries if the need should arise. In short, the Iowa industry can satisfy the demand for both greater volume and higher quality than it produces at present.

COAL STORAGE

Although the perennial problems of coal storage are troublesome at any time, with labor interruptions being what they are, they are especially pressing in wartime when it becomes imperative to level off the seasonal peak loads of already overtaxed transportation systems. Spontaneous heating is a phenomenon more or less common to all bituminous storage piles whatever the rank of the coal (short of the Pocahontas types perhaps). In his professional experience, the author has had occasion to answer many inquiries from the dock traffic, with its high-rank fuels, which was encountering storage trouble.

However, as with the animal kind so with coals, with age and maturity come moderation and tranquility, and the more acute storage problems are associated with the more chemically active low-rank coals of the Middle West.

As a result of the work that has been carried on in this field of study for many years, and with a voluminous literature available the methods and techniques for supressing or controlling self-heating are fairly well established. Among the fundamental principles to be observed are (1) provision for homogeneity of the coal mass to be laid down, best obtained by screening or other classification; (2) horizontal stratification of increment layers to obviate drafts induced by chimney effects; (3) use of maximum practicable pressure in building the stack to give the structure a density that will inhibit diffusion of air from without. Experience has shown that, with careful observance of these rules, Iowa coals may be stored for long periods if not indefinitely with only moderate deterioration in heat value. In this connection, among the more significant storage tests which have been made were those at the John Morrell packing plant at Ottumwa carried out by the chief engineer of the company, Mr. Barney Winger. The coal selected (6-in. lump from neighboring mines) was dumped from a traveling hoist and piled to a maximum height of ten feet with only moderate packing. Examination of one of the early piles two years after it was laid down disclosed a crust of air-slacked coal ten inches deep, under which the coal was fresh and in good condition. At the end of the third year, the slacking had extended to a depth of about fifteen inches, but in all this time no evidence of undue heating was observed. While six-inch lump was used in these tests, it is quite probable that a smaller size, say two-inch, would have given equally good results, as proved by similar tests made at the University of Iowa.

Even more striking, because they involved the storage of Iowa $1^1/_4$-in. screenings, were the results obtained by the Iowa Electric Light and Power Company at its Marshalltown plant. A 3000-ton pile put down in early summer, firmly packed with horse-drawn drags, kept perfectly until consumed late the following fall without showing any abnormal rise of temperature, although loose piles of the same kind of coal ignited in less than two weeks.

Tests of four or five months' duration on two-inch Iowa nut, made on numerous occasions at the University power plant, have been uniformly successful. Inasmuch as an undue temperature rise, if it comes at all, comes quickly, it is safe to assume that immunity from trouble was attained. It is important to repeat that nothing less than the punctilious adherence to the simple rules laid down will insure safety in the storage of any high-volatile coals, whatever their source may be.

PROBLEM OF ASH FUSION

Although the curse attendant upon low-fusing ash falls mainly upon the users of certain types of burning equipment only, its threats are sufficiently general to keep most of the consumers of Midwest coal continually on the alert. It is an ironical turn of justice that Nature in laying down the great coal beds of the country should give to the fuels of the Appalachian region not only the high qualities recognized in their organic components but for good measure endow them with the seemingly unrelated quality of high ash fusion. Conversely, associated with the lower ranks and grades, we find as a rule the more fluid mineral residues. The importance of this variable factor in the fuel in the design of plant and equipment is appreciated of course by every engineer, but sometimes he underestimates it or perhaps merely stretches his luck beyond the elastic limit.

Iowa coal ashes are not the most fusible of those produced in this region; that dubious honor should go perhaps by photo-finish to those from Illinois veins Nos. 1 and 2. However, they do occupy the lower ranges around 2000 F, along with many others from Illinois, Missouri, and Kansas, in comparison with points as high as 2500 to 3000 F for certain West Virginia ashes. Long observation and experience at the Univeristy power plant, in which some half million tons of Iowa coal have been burned in the last ten years with three different types of equipment, have yielded a fairly sound basis for drawing conclusions. The natural-draft chain grates with which the plant was originally equipped in 1927 have taken in their stride without faltering coals ranging in ash from 10 to 25 per cent, regardless of what the ash-fusion points may have been.

When in the interests of higher economies the introduction of underfeed stokers was being considered, grave doubts were expressed. Not until the exhaustive acceptance tests of the first unit finally installed were completed, and it had given months of satisfactory service, were those doubts finally dispelled. After years of service of this unit and of two more acquired later, with coals from perhaps a score of Iowa mines, it seems evident that the explanation lies in part at least in the blanketing effect a large volume of ash exerts on the tuyères, in the absence of which fusion and stoppage might easily occur. In brief, a fault becomes a virtue of sorts.

Herbeck's success at Cedar Rapids in burning a washed Illinois No. 2 coal of less than 10 per cent ash and with an ash-fusion point of about 1930 F on underfeed stokers, in spite of air preheating, is familiar to most fuel engineers, but it was attained only by water-cooling the tuyères. The question of what might have happened on the original grates had the fuel

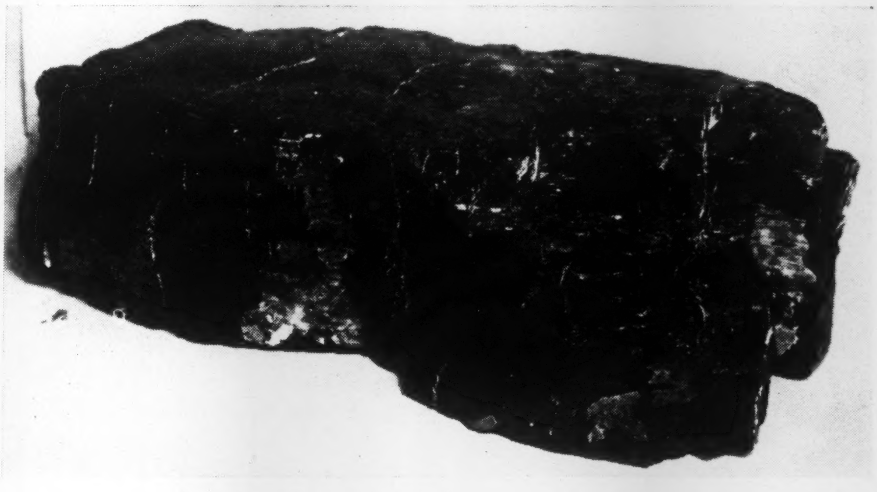

FIG. 3 IOWA COAL WITH MINERALIZED CLEAVAGE PLANES

carried its raw burden of 15 to 20 per cent ash is perhaps still open. Doubtless, for complete insurance, tuyère cooling should be provided whenever underfeed stokers are used with coals of low fusion point.

The University plant experience has not all been rosy. A certain bony coal or "false bottom" is particularly deadly to the fireman's peace of mind and when on infrequent occasions such structures escape the mine loader's vigilance and they descend in quantity upon the plant, the reaction is sudden and violent, an eruption of devil's broth that forces the unit out of the line. A happy solution of the problem seems to have been reached in the recent installation of two Detroit spreader units which combine the grate-cooling facilities of the old-type chain with the effective fuel distribution and combustion control needed for satisfactory economy. In the years they have been in service, they have taken the best and the worst with equal ease.

In pulverized-firing practice of Iowa coals, much study appears necessary before satisfactory operating conditions are to be attained. In a large central Iowa plant, where grave difficulties with "icicles" have been encountered, Fig. 4, the fuel used is unfortunately drawn from a screenings jackpot supplied by numerous mines, many of them poorly equipped for producing clean coal. It is interesting to speculate on how much the difficulties could be overcome were the fuel first treated in a modern washery to reduce not the melting point of the inherent and residual ash, perhaps, but the gross burden of the separable mineral.

IOWA COALS AND THE DOMESTIC MARKET

However, quite as important to the war effort, possibly, as the supply of fuel to the industrial furnace is the reduction of the burden now carried by our transportation systems by the creation and maintenance of facilities for producing the high-grade domestic fuel that now must come in large measure from without the borders of the state. One of the phenomenal developments of the last decade has been the rapid increase in the use of the domestic stoker, designed to give the householder the luxury of automatically controlled and uniform heat at the low cost of coal fuel. But modern stoker coals must measure up to exacting standards both of fuel value and cleanliness. Thus it happens, that the large producers of Illinois with their modern cleaning equipment are in a more favorable position to supply fuel to the Iowa consumer than the local industry is itself.

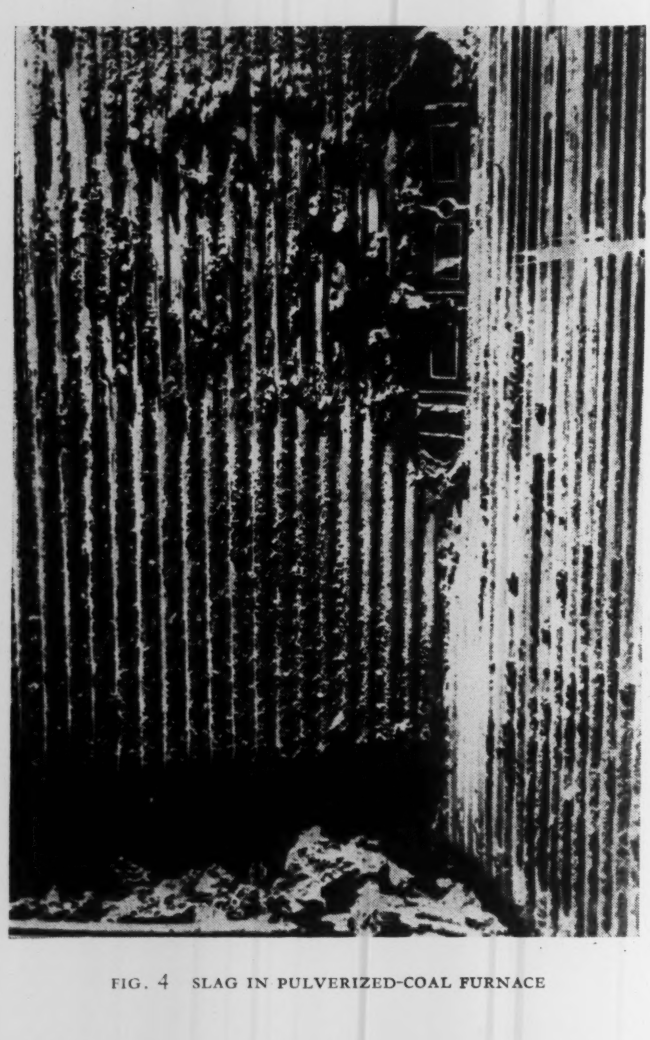

FIG. 4 SLAG IN PULVERIZED-COAL FURNACE

A four-year program of work just completed at the University, results of which have been reported,[1] covers a comprehensive survey of the possibilities of converting low-grade screenings, carrying as much as 25 per cent of ash, into premium stoker fuels, uniform in quality and size and carrying only 10 per cent or less of ash.

The recommended method involves the use of the Deister-Overstrom table which is chosen rather than any of the standard jig machines because of the relatively low capital investment required for the small unit that would most nearly fit the needs of the average Iowa mine operator. Industrial models of this machine with capacities of ten to fifteen tons per hour are in successful commercial use in Illinois and Missouri and are converting dirty screenings of little market value into excellent domestic fuel.

A random selection of a run in the Iowa Series shows a screenings shipment with 22.2 per cent ash (dry basis) reduced to 10 per cent ash and a recovery of 75 per cent of the gross tonnage. Picking table refuse from a large strip operation, carrying 21 per cent, was reduced to 11.5 per cent ash with a 75 per cent recovery of what would otherwise have been wasted. In a very direct sense, the development of a stoker-fuel industry would promote the welfare of the business in the state and at the same time a real, if indirect, advantage would be given the war program through decentralization of a seasonal industry that makes heavy demands upon transportation. We carry too many coals to Newcastle. As the meat-packing industry of Iowa long ago learned that a steer raised in the state could be profitably slaughtered in the state, so the mining industry may take its cue.

SUMMARY

In summation, the Iowa mines with their ample potential reserves are ready to meet moderately increased demands; the problems of storage, even if relatively more difficult than in other regions, are nevertheless susceptible to solution. The successful burning of Iowa coal is dependent only upon appropriate furnace design and adequate control. Much can be done to decentralize the fuel industry as a whole and thus aid the war effort, by stressing the development of certain phases of the home industry.

AS A result of successful experiments made over the past three years with a loud-speaker system in one department, an entire St. Louis manufacturing plant has been completely equipped to broadcast to all factory workers. The system is used to broadcast musical recordings and on occasion is used to transmit important or exceptional radio programs.

A recent check-up by an outside agency shows the following results:

1 The general idea and programs one hundred per cent approved by workers.

2 Only musical programs are put on.

3 Workers put in from 5 cents to 10 cents per week, all voluntary contributions, to cover cost of new records.

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[1] "The Preparation of Coals From Iowa Screenings," by H. L. Olin, University of Iowa, Studies in Engineering, Bulletin No. 28, 1942.

Influence of MACHINE DESIGN *on* LUBRICATION

By W. G. G. GODRON

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TWENTY years or more ago machine designers were talking about tolerances in terms of thousandths of an inch. Ten years ago tolerances had begun to shrink to ten thousandths of an inch, and today some tolerances, particularly those of surface finish, are held to microns. In those earlier days, when steam engines were still the major prime movers, steam turbines were beginning to find their place in the sun, and later Diesel engines were struggling toward practical operating designs. Since the dawn of the century, there have been rapid changes in the entire machinery picture. The steam turbine has grown to large sizes, producing tremendous quantities of power. Diesel engines have taken a strong position not only in production of power but also in automotive work. Aviation engines are advancing in power and in design from day to day. The tremendous emphasis placed upon production machinery has brought about great changes in their designs and efficiency.

All of these changes have resulted in greatly increased pressures, temperatures, and speeds, requiring advances in the design of lubricants. Today as yesterday machinery will not operate unless properly lubricated, and lubrication is now as always a major factor in uninterrupted production.

Regardless of the machine, its use, or design, all machinery consists of three fundamental parts, i.e., bearings, gears, and cylinders. The basic principles of lubrication for any one of these three parts apply to them regardless of the machine in which they operate.

Design and design changes have influenced the operating conditions of machinery. These operating conditions have a definite influence on lubrication. The problem of producing lubricants for a new design is also affected by the efficiency of that design and by its effect upon conditions which would tend to be detrimental to lubrication. In some cases, the design can be changed to improve lubricating conditions while, in other cases, designs cannot be changed, and it is necessary to produce special materials to meet severe operation.

Friction affects all machinery operation whether it be the rubbing of a shaft on a bearing, the sliding of a piston in a cylinder, or the rolling and sliding of gear teeth over one another. Bowden has stated that "the physical processes which occur during sliding are too complicated to yield easily to simple mathematical treatment." Since the reason for lubricating is to reduce or eliminate friction, let us first examine friction itself.

GENERAL CONSIDERATIONS OF FRICTION THEORY

In general, friction has been divided into two states, i.e., static friction and friction of motion. There appears to be good evidence of continuity between these two states; but for simplicity of discussion, we will consider first what happens when two dry metal surfaces are in contact and not in motion. To simplify the matter, let us consider two flat steel plates, one laid upon the other with a load applied on the upper plate. Even though the surfaces may be wiped clean, a film of adsorbed material from the air, such as dust or greasy particles, and a thin oxide film will still adhere to these surfaces. The thickness of this film, as reported by Hardy, is of the order of one millionth of a millimeter. It is impossible to obtain absolutely clean surfaces, except under very rigidly controlled laboratory conditions. There will always be a certain difference in general surface contour of the two plates, even though they may be machined and ground as perfectly as is possible with present equipment. The actual contact between these two plates will, therefore, be confined to those areas where the contours of the surface permit intimate contact. Within these comparatively large areas, there are microscopic surface irregularities which will be the first points of intimate contact. This microscopic contact area is not affected by the size, shape, or the roughness of the surface. It depends mainly upon the load applied, not upon the apparent area of the surface.

Various investigators have utilized electrical-conductance methods for measuring the actual contact areas; and Bowden records that at 3 psi the actual magnitude of contact area is $^{1}/_{10,000}$ while at 44 psi it will be $^{1}/_{130}$. This means that the total pressure is resisted by the surface irregularities which are crushed down or possibly deformed elastically until the total cross section of contact is sufficient to support the total load. Increase in pressure will increase the area of contact points.

At these contact points, the pressures normally will be extremely high and sufficient to rupture the thin film of contamination from the air which could not be cleaned off by normal methods. At the points of irregularity, therefore, the two surfaces of the steel plates are actually touching, that is, they are within the range of the molecular forces of cohesion of the surfaces. The same force of cohesion, which holds together all of the molecules of each steel plate, holds the two plates together at these points of contact. It might be said that tiny bridges are formed between the plates and, at these points of contact, the two surfaces have become one. These bridges are large in relation to molecular dimensions.

If we now attempt to slide the upper plate over the lower one, these minute bridges will be placed in shear, and, as motion continues, they will be torn apart. The breakage will occur at the weakest cross section of the bridge, which may or may not be its original surface of contact. Under the crushing forces of contact, which it must be remembered are extremely high at these minute points, the metal below the surface molecules is placed under stress and deformed. This deformation may tend to alter the structure of the surfaces over the small areas and can influence to some extent the change of conditions. The motion and the tearing of the metal bridges cause heat which, it has been estimated, occurs in flashes of the magnitude of 0.001 sec. If a sufficient quantity of heat is released by the tearing apart of a number of these bridges over a short interval, the heat cannot be dissipated rapidly enough through the metal and sometimes the melting point of the surface is reached.

The motion of any two surfaces in actual contact over each other results in tearing or scratching the surfaces. Hardy found that a glass slider moving over a glass plate, when both were perfectly clean, caused seizure between the two glass parts and a tearing out of flakes of glass in a trail where the motion took place. The same action has been observed in the case of metal sliders and plates.

Presented at a joint meeting of the St. Louis Section of the Society of Automotive Engineers and the St. Louis Section of The American Society of Mechanical Engineers, St. Louis, Mo., January 22, 1943.

HOW LUBRICATION SUPPLIES THE ANSWER TO FRICTION

According to research work by Bowden and Kaikin, moving surfaces show a constant fluctuation of area of contact and intermittent "stick-and-slip" motion. Under such conditions it is obviously impossible to maintain motion between surfaces since they are rapidly undergoing destruction. Bearings, gears, and cylinders would wear out quickly, the useful life of the machine would be brief, and the maintenance cost exorbitant. In order to overcome this condition, a lubricant must be used. Lubrication reduces or often eliminates metallic friction.

Now let us revert to a consideration of the original steel plates and apply a film of oil to the surfaces. The oil molecules on and very near each surface will be under the influence of that surface and attracted to it. Since the attractive force diminishes with the distance away from the surface, the oil molecules farther away from the surface will be held together only by the cohesion between the oil molecules. The molecules of oil in actual contact with the surface or within the range of surface influence will attain a certain quality of rigidity, which is not found in the oil itself, and the shearing action which occurs will be a function of the magnitude of the bonding force between the metal surface and the oil molecules. In other words, the rigidity of the oil molecules, within the influence of the surface attraction of the metal, has a far greater effect upon the resistance to movement or shear in this thin film than the actual viscosity of the oil.

Actually there are two thin films of oil, one on the surface of each plate which comes within the influence of the surface. Between these two zones the oil is free from the surface influence and will act as normal fluid oil.

As the plates lie one upon the other, the oil is gradually forced out by the pressure toward the edges of the plates, and the total film thickness decreases until the highest irregularities of the surfaces approach each other. If pressures are low, the thin film on each metal surface may be sufficiently strong to remain in place without being forced off the irregularities, and thus actual metallic contact and "bridging" will be avoided. If pressures are high enough, the thin surface film of the lubricant on the irregularities will be displaced and actual metallic contact with bridging will occur. Some types of molecules are not easily displaced, but many of these are not suitable lubricants since they are highly unstable and tend to break down or form materials corrosive to the metal surfaces.

If we attempt to slide the upper metal plate over the lower, employing comparatively light actual loads and low velocities, it may be possible to prevent metallic contact. However, in practical operation, it will be found that a certain amount of metallic contact will occur, with consequent gradual wear or destruction of surfaces, although with the more suitable lubricants, the rate of wear will be greatly diminished.

BOUNDARY AND FLUID-FILM LUBRICATION

This state of lubrication is called "boundary lubrication." Some investigators (notably Hardy) prefer to limit the term "boundary lubrication" to the state in which the total thickness of the oil film is equal to or less than the thickness of the two films which are within the influence of the metallic surfaces; and to call thin films which are thicker than this, a state of "thin-film lubrication" or "quasifluid lubrication." For the sake of simplicity, we prefer to define "boundary lubrication" as the state in which the oil film is not sufficiently thick to prevent some metallic contact, no matter how slight, between surface irregularities. "Fluid-film lubrication" may be defined as the state in which the oil film is sufficiently thick to prevent any contact between surface irregularities.

With boundary lubrication wear must occur and may be serious or so slight as to be practically unnoticed; while if full fluid films are maintained there will be no wear. Boundary films are usually found where two surfaces of contact are equidistant at all points or, in other words, have the same contours, which in the case of annular bearings would mean that the contact surfaces of shaft and bearing would have the same radii. In actual service conditions metallic rubbing surfaces operating on boundary films are supplied intermittently with oil, and therefore the lubrication between the shaft and bearing or piston rings and cylinder may fluctuate between what some investigators have called boundary film and thin fluid film.

EARLY METHODS OF LUBRICATION

In early machinery designs having radial bearings, loads were comparatively light, speeds were low, and temperatures were moderate. Lubrication was accomplished by means of various types of fatty materials fed by hand application, drop feed, or waste packing. It is of interest to note that two lubricants, recommended as excellent in a mechanical dictionary of 1875, were a mixture of 4 parts of tallow and 1 part of black lead; and a mixture of tallow, beeswax, soda, and glaubers salts. Other lubricants such as castor oil and fish oil were also used before the advent of petroleum products.

While the shafts were fitted in their bearings with what today would be considered large clearances, bearings were carefully scraped and fitted in order to secure maximum area of contact and thereby reduce unit pressures. This means that the rubbing surfaces of shaft and bearing have the same radii and thus are parallel. These bearings all operated on boundary films. As pressures and speeds began to increase as a result of better design practice, it became necessary to increase bearing areas and to scrape and fit them more and more accurately, because as we have seen from our previous discussion of boundary lubrication, temperatures also increased and wear became more severe.

Although we do not have accurate information concerning the first engineer who used the circulating oiling system, it is reasonable to believe that this was done mainly to renew the boundary film more constantly and to provide better cooling for the bearing rather than to produce what we would now call the full fluid film of lubricant.

It was not until 1883 that Beauchamp Tower carried on his experiments in friction with a half bearing to find that it was impossible to correlate his tests unless the bearing operated in a bath of oil. He further discovered that actual "hydraulic pressure" was produced in the oil film and that it was extremely important in the production of a perfect lubricating film to introduce the oil into the bearing at a location which was not in the pressure area. Tower's work was the beginning of the study of full fluid film, which has resulted in present-day pressure circulating systems used in modern machinery. Without the full fluid film, it would be impossible to operate many of our contemporary machines. We can readily conceive why the development of machinery design was stopped when it reached the limitations of lubrication with boundary films and could not continue until full-fluid-film lubrication was developed.

For example, in boundary-film lubrication of annular bearings with pressures exerted constantly in one direction, the clearance of the bearing, so long as it is not so tight that seizure will take place, is unimportant. The only part of the bearing which does any work is the part covered by the pressure area which may be one quarter to one third of the circumference. The cap or upper half of the bearing is more or less a strength member, also designed to keep out dirt.

In full-fluid lubrication of an annular bearing, clearance becomes very important, as will be discussed later.

ACTION OF FULL-FLUID LUBRICATION

Let us review what happens in full-fluid lubrication when a shaft begins to rotate in a plain bushing-type bearing with correct clearance and without scraping of bearing surface. The shaft is at rest lying on the bottom of the bearing, the width of the contact area of course being extremely small. A stream of oil is introduced into the bearing clearing space, practically surrounding the shaft. The shaft begins to rotate and climb up the side of the bearing, but the moment movement starts the shaft begins to draw oil down between itself and the bearing. Consequently, the shaft begins to slip back. The adhesion of the oil to the shaft surface causes the oil to be pulled along by the shaft and between it and the bearing. As speed increases, this "pumping effect" increases until there is a hydraulic pressure on the incoming side between the shaft and the bearing which displaces the shaft slightly from the vertical center line and lifts the shaft off the bearing. As the shaft rotates faster and faster, it tends to pull more and more oil between the shaft and bearing and lift the shaft farther from the bearing surface.

The hydraulic pressure of the oil film increases and forces the center line of the shaft up and away from the incoming oil side of the bearing until maximum speed is reached. The oil is then in the shape of a wedge under the shaft, extending for a certain distance past the center line.

If we were to use the construction of shaft and bearing, as discussed before under boundary lubrication, wherein the shaft and bearing have the same radii in the contact area, an oil wedge could not be formed, since wedges cannot exist between parallel surfaces. Thus in order to secure the oil wedge necessary for satisfactory operation under high pressure, correct design of the bearing requires a smaller radius for the shaft than for the bearing in the pressure area.

The oil wedge at its thinnest point must be maintained sufficiently thick to separate all metallic irregularities in order to prevent wear. This thickness of film is controlled by the unit pressure on the bearing, the speed of the shaft, and the viscosity of the oil at the operating temperature. The efficient formation of the oil wedge is effected by applying the lubricant at the proper point and in sufficient quantity. Oils should always be applied at a location well outside the pressure area. The quantity of oil fed is ordinarily ample to secure the benefits of cooling. The distribution of pressure along the axis of a bearing is represented by a comparatively flat curve which falls rapidly at the ends. The pressure distribution across the oil wedge rises rapidly from the incoming end to reach a maximum at the thinnest part of the wedge and then falls abruptly.

Since this oil wedge transmits the pressure directly to the bearing, the distribution of load on the metal will be the same as in the oil wedge. The bearing must therefore always be strong enough to support the maximum unit pressure without failure. Cases of such bearing failure, where the metal was actually squeezed out without failure of the oil wedge, have not been uncommon.

The earlier soft babbitts were unable to support gradually increasing unit pressures. A change was made to tin babbitts, and later to thin films of babbitt supported by stronger backing metals. The copper-lead, cadmium, silver, and other harder bearing metals were developed to accommodate the ever-increasing pressures. Even with these harder metals, failures occurred when heavy or shock loads caused deformation of the bearing. Such deformation, particularly where thin oil wedges are involved, may change the bearing contour sufficiently to destroy the possibility of formation of an effective oil wedge.

CONDITIONS WHICH AFFECT BEARING LUBRICATION

Let us consider some of the other conditions which affect lubrication of bearings of this type:

All of the oil fed into the bearing must eventually come out at the ends. If clearances are too large, there may be such a rapid leakage that not enough oil will be available to form the necessary oil wedge. The effect of leakage on a bearing comparatively short in proportion to diameter would be greater than in long bearings. If clearances are too small, there may be insufficient space to permit an adequate supply of oil to form an effective oil wedge. In other words, the correct difference between shaft and bearing diameters (clearance) is extremely important for heavy-duty operation. These particularly severe operating conditions are found in the circulating oiling systems of the bearings of aircraft, high-speed Diesel engines, and in some high-speed precision machine tools.

It is obvious that the oil supply must be introduced at some point outside of the pressure area, in order to maintain a full supply of oil to form the oil wedge. Grooves in the pressure section not only reduce the total area and increase unit loads, but they form small canals permitting oil to escape easily and thus interfere with maintenance of the hydraulic pressure in the oil wedge. Whenever oil grooves must be used sharp edges should be avoided by chamfering them well.

Generally speaking, static friction must be overcome in the starting motion in any bearing, no matter what type of films will be formed later. It is seldom of any practical importance excepting where rubbing or sliding begins under maximum operating load, such as in Kingsbury or other thrust bearings, on hydraulic turbines, or the sleeve bearings of horizontal turbines.

Another case where static friction may have an important effect on efficiency of operation is in the movement of the slides of some precision machine tools. In this case, static friction may cause "chattering" and spoilage of work. Motion of such slides is frequently extremely slow and may include pauses of some length. With this type of motion between slides and ways, "stick and slip" as discussed before will occur unless an oil is used which has very strong boundary films.

One of the most important fields of boundary lubrication is in the lubrication of the pistons, rings, and cylinders of Diesels, aircraft, and all mobile equipment operating under heavy duty. Two distinct problems are involved: (1) Lubrication between the piston rings and the cylinder; and (2) between the piston and the cylinder wall.

In case 1, the really difficult problem is the efficient lubrication of the top piston ring at the beginning of the power stroke. This is one of the extreme examples of boundary lubrication. Here we have to deal with high gas pressures behind the rings, high temperatures of the surfaces, and a slow motion which allows time for squeezing the lubricating oil from between the surfaces.

The development of high gas pressures is necessary in order to secure the increased power required, and so far not much has been done with design to reduce the action of the gas pressure on the piston rings. The high temperatures are also a natural result of this power increase, but design can and has helped to improve this condition, through such means as more efficient combustion chambers and cooling of cylinders and pistons.

In case 2, the piston presses against the cylinder wall as a result of the angularity of the connecting rod. Although the total force is not great, the necessary difference between the radius of the piston and that of the cylinder produces a theoretical line contact with only a boundary film present which, however, may result in a very high unit pressure. The sliding motion between these surfaces is parallel to the line of contact instead of at right angles as is found, for example, in spur-gear teeth. This piston lubrication can therefore be one of the most difficult of lubricating problems. It is not surprising that scoring of pistons and cylinders is all too common in operation, particularly in new engines.

The designer attempts to alleviate this condition by maintaining the smallest possible practical difference between the cylinder and the piston diameters. This with the use of the correct oil, widens the actual area of contact and reduces unit pressures. If piston speeds and pressures between pistons and cylinders increase still more, it may even be necessary to start with a better rubbing contact between the piston and the cylinder. This could be accomplished by using the same radii of piston and cylinder over the thrust area of the circumference.

(Continued on page 359)

MAINTENANCE *of* ELEVATOR MECHANICAL SAFETY APPLIANCES[1]

Elevator Service Bulletin No. 2[2]

II GOVERNORS AND SAFETIES[3]

1 IMPORTANCE OF ADEQUATE SAFETIES

THE safety of the passengers in an elevator is ultimately dependent upon the adequate performance of the safety device and its associated mechanism. Therefore, it is of the utmost importance that they be maintained in proper working condition. There are many safeties in use today which would not stop and hold the elevator to which they are attached were the cables to part; therefore, the safety should be tested by competent elevator mechanics at least once each year to determine that it is in proper working order. Defective equipment should be repaired or replaced.

2 GOVERNORS

2 The proper functioning of a safety is dependent upon the proper operation of the equipment discussed in the following paragraphs.

(*a*) *Clearance of Governor Parts.*

3 The flyballs of the governor (where this type of governor is used) must have adequate clearance from fixed or temporary obstructions to permit them to actuate the tripping mechanism of the rope grips. The clearances should be checked by lifting the flyballs well above the position at which rope grips lock and revolve them at this level. This test will also clear the spindle of congealed oil, grease, or dirt.

(*b*) *Clearance of Governor Rope.*

4 *With the elevator running*, check the clearance of the governor rope and eliminate any interference.

(*c*) *Governor-Sheave Inspection.*

5 Check the governor drive sheave to see that it runs free and true; that the shaft or bearings are not worn excessively; and that there is no apparent slip of the governor cable when the elevator starts and stops. If there is apparent slip, eliminate any undue governor friction, and, if necessary, shorten the governor rope so that the idler does not bottom, or add more weight to the idler.

(*d*) *Examination for Wear and Freedom of Action.*

6 Examine the linkage and rope-grip attachment for undue wear. Properly lubricate all bearing surfaces. Comparatively slight wear of the pins, links, and particularly of the split collar to which the links are attached, can cause a very considerable rise in the tripping speed.

(*e*) *Sluggish Action of Governor.*

7 Sluggishness may be the result of paint on pins and other bearing surfaces. Governors should, preferably, not be painted after they are installed. If it is necessary to paint the governor, surplus paint should first be removed from the brush, and no rotating or sliding surfaces or electric contacts should be coated. Clean all bearing surfaces and relubricate them. After the paint is dry, test the governor for free operation.

(*f*) *Governor Switches.*

8 Where governors are equipped with adjustable electric contacts, the adjustment should be such that the contact will open well in advance of the setting of the governor jaws. This setting should be made by a competent mechanic, preferably one employed by the company that made the elevator installation. If the switch fails to open before or, in the case of nonadjustable contacts, at the time the rope grips lock, this condition must be corrected before the elevator is returned to service.

9 Some governors are equipped with an additional switch to regulate the speed of the elevator. This switch should be examined to see that the contacts are in good condition. Any change in the setting of this switch should be made only by a person entirely familiar with the particular control system used.

(*g*) *Condition of Governor Jaws.*

10 The jaws of the governor should be examined to make sure that they will not permit the rope to be pulled through with too low a tension. The entire retarding force of wedge-clamp safeties, which at present are the most common type, is derived from the tension in the governor rope. If this tension is too low, the safety will not be applied with sufficient force to stop the car. This is particularly important where the ropes have parted on a traction machine, whereby the effect of the counterweight is lost and the safety must stop the entire weight of the car and load.

(*h*) *Setting of Governor Jaws.*

11 Many high-speed governors are designed with a spring-backed jaw, permitting the governor rope to be pulled through the rope grips after the requisite tension has been reached. This spring adjustment, if provided, should never be changed except by a trained mechanic familiar with the particular safety system, and he should know exactly what the pull-through value should be for that particular safety. This value varies from manufacturer to manufacturer and may vary considerably between two different types of governors or safeties made by the same manufacturer. This spring on the governor jaw should be examined to see that it is intact, in the proper position, and supplying enough pressure on the floating or movable jaw.

(*i*) *Governor Rope.*

12 The condition of the governor rope is of the utmost importance. If this rope fails, it will be impossible to apply a wedge-clamp safety at all, and some of the newer self-actuating types may fail to pull in far enough to act. Governor ropes, which are generally of iron, run over relatively small sheaves and are very lightly loaded, all of which tends to cause fatigue failure. A further discussion of this type of failure, and a

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[1] Prepared by the Executive Committee for the Safety Code for Elevators, Dumbwaiters, and Escalators of the American Standards Association.

[2] Bulletin No. 1, Elevator Wire-Rope Maintenance, appeared in MECHANICAL ENGINEERING, February, 1943, pp. 110–112.

[3] Part I, Introduction, omitted from this installment, is substantially the same as appeared in connection with Bulletin No. 1.

method of testing ropes to indicate their condition, are included in Bulletin No. 1,[2] now available as National Bureau of Standards Bureau Circular C441, Elevator Wire Rope Maintenance[2] which may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C., at 5 cents a copy. The American Standard Safety Code for Elevators provides:

> Tiller-rope construction shall not be used for govenor cables except that tiller rope may be used for the portion of the cable wound on the safety drum.

3 RELEASING CARRIER

(*a*) *Importance of Proper Functioning.*

13 The governor rope is ordinarily attached to the car by means of a spring-backed carrier ("pull-out shackle"), which serves to drive this rope and through it the speed governor. When the car is being accelerated the tension in this rope is increased owing to the inertia of the rope itself and of the governor mechanism. On high-rise elevators the mass of the rope is considerable and, with the high values of acceleration used in such elevators, produces a considerable tension in the governor rope during the period of acceleration or retardation. This tension is sometimes great enough to pull the shackle from its holder. Mechanics sometimes lighten up on the holding spring to prevent such an occurrence. Unfortunately, in the case of many releasing carriers now in service it is possible to tighten this spring until its pull-out value exceeds the pull-through value of the governor jaws, in which case the safety will not be applied when the governor jaws set; in fact, the carrier mechanism on the car may be mechanically locked on the shackle so that it cannot be pulled apart except by physically deforming the car mechanism or the shackle.

(*b*) *Pull-Out Test.*

14 When checking the safety equipment on a car, be sure to test this releasing carrier. A mechanic and helper should be able to pull the governor rope free from the carrier without the use of tools or levers, except in extremely high-rise installations. If two men cannot pull the shackle from the carrier by direct pull, the tension on the carrier spring should be adjusted until this can be done. The proper setting may also be tested by tripping the governor rope grip jaws by hand and then running the car downward at slow speed until the shackle is pulled from the releasing carrier.

(*c*) *Socketing of Ropes.*

15 The socketing of the governor and safety ropes should be checked. If babbitt is poured too cold, it may not have filled the spaces between the strands, resulting in a defective fastening, and the drum or governor rope may be pulled from its socket before the proper operating tension is reached.

(*d*) *Inspection of Drum Rope.*

16 The condition of the safety drum rope is very important. The American Standard Safety Code for Elevators requires corrosion-resistant material for this rope, but many elevators are still equipped with drum ropes of iron or steel. Iron or steel drum rope should be carefully inspected, since it does not move nor is it subject to tension except during an application of the safety. Corrosion is particularly rapid in locations where steam, brine, or excessive moisture is encountered. Frequently, in apparently dry hoistways, drum-rope corrosion will occur owing to an excess of wash water being used in the mopping of cars or the condensation of moisture from warm saturated air entering a somewhat cooler elevator hoistway.

(*e*) *Care and Maintenance of Drum Rope.*

17 During the present emergency, iron or steel ropes may possibly be used extensively as drum ropes owing to the extreme shortage of critical materials. If corrodible drum ropes are used, they must be kept well lubricated, examined at frequent intervals, and renewed whenever the governor rope is replaced.

4 UNDERCAR SAFETIES

(*a*) *General.*

18 The design of an adequate undercar safety involves the consideration of many factors. It must be strong enough and exert sufficient force to stop and hold the car with a reasonable overload. The retarding force is the product of the pressure of the jaws on the rail multiplied by the minimum coefficient of friction. Rail lubrication should be limited to light oil or grease, as this type of lubricant will be squeezed out when the safety is applied. Solid lubricants, such as graphite, white lead, talc, sulphur, and similar materials, must not be used, as they will materially reduce the coefficient of friction. The tough black coating which accumulates on rails in some hoistways (particularly where the guide shoes cover only a portion of the finished faces of the rail) may similarly seriously affect the operation of the safety.

(*b*) *Instantaneous Safeties.*

19 On instantaneous safeties it is important to check the point at which the rollers engage the rails. This may be checked by two men under the car, one at each rail, watching the position of the rollers as the lever to which the governor rope is attached is slowly lifted. Rollers should touch the rail and inclined surface at the same time. The point of contact should be below the center of the incline. Rollers that show any cracks, wear, or deformation should be replaced. Any dirt, grease, or other foreign matter must be removed from the pocket before the lever is reset. When the trip lever is released, each roller must return to its pocket and be clear of the rail. The releasing mechanism should be so adjusted that normal acceleration or a sudden jar will not cause application of the safety.

(*c*) *Wedge-Clamp Safeties.*

20 All moving parts of a wedge-clamp safety should be kept well lubricated and should work freely. Pulling the drum rope by hand should cause the drum to revolve to the position in which the rail grips bear on the rail surfaces. Most wedge-clamp safeties provide some lateral play of the drum and shafts, so that if one wedge is engaged before the other, the entire assembly may move toward the wedge that is not in contact with its rollers before appreciable force is applied to the first rail grip. In checking a wedge-clamp safety be sure that this equalization can take place before the drum or stop collar on either shaft brings up solid on the bearing or thrust plate.

21 On the type of safety in which the safety rope is run over two sets of sheaves, one set attached to each wedge of a wedge-clamp safety, care must be taken to see that all parts are properly lubricated, and that each run of the operating rope is in the proper groove when the device has been reset.

(1) *Lead Sheaves.*

22 Examine drum-rope lead sheaves to see they are securely fastened and correctly located. Lag-screw fastenings must not be used and, if found, must be replaced with through bolts.

(*d*) *Flexible Guide-Clamp Safeties.*

23 Parts should be inspected to see they are working freely and that pockets for rollers are clean and free from dirt or grease.

(*e*) *Spring-Actuated Safeties.*

24 With safeties in which the actuating force is derived from coiled springs kept under almost full compression, it is particularly important that tests be made to determine that such safeties will stop and hold the fully loaded car from contract speed.

(*f*) *Resetting Safeties.*

25 A jammed drum rope will prevent proper operation of the safety and has been responsible for some of the most serious accidents ever recorded. After the safety has been set either by governor action or by pulling the cable out by hand, a tension

must be maintained on the governor or drum rope while the drum is being turned to make sure this rope will not jam but wind in the groove provided. In resetting all of these safeties, care should be taken to see that the shackle is fully returned to the releasing carrier and that all actuating parts of the safety are clear of the rails.

(*g*) *Cleaning of Safeties.*

26 In order to insure prompt and effective action and to decrease the possibility of accidental setting of certain types, all safety devices should be thoroughly cleaned at regular intervals. Cleaning will tend to decrease corrosion and prevent the absorption of oil by dust and lint. Following the cleaning, the operating parts should be relubricated.

(*h*) *Clearance of Safety Jaws.*

27 Note whether under normal operating conditions (i.e., with the governor-rope shackle properly held in place in the releasing carrier), the wear or play of the guide shoes is great enough to permit the safety jaws to rub on the three contact surfaces of the guide rails. This may be determined by placing the car at a convenient location and using a lever to pry the car toward each surface of the rail on both sides of the car frame or by placing an eccentric load in the car. A thickness gage or a piece of paper may be used as a feeler to determine the clearance between each safety jaw and the rail surface when the car is in its extreme position. In making this test, care should be taken not to apply sufficient force to the lever to spring the guide shoes. Guide shoes should be replaced before the safety jaws touch the rail. When guide shoes are worn, safety jaws should be examined and must be replaced if worn. In some cases it may be necessary to remove the safety jaws for inspection and measurement.

(*i*) *Need for Periodic Tests.*

28 Regardless of the type of safety, the device should be tested for its ability to stop and hold the car and contract load from governor-tripping speed or, where this speed cannot be reached, the maximum obtainable speed in the down direction. If on test the device fails to do this, it must either be repaired and retested or replaced by a new device. Each car safety should be tested at least once each year by competent elevator mechanics to see that it is in proper operating condition.

III GUIDE RAILS

1 PURPOSE

29 The functions of elevator guide rails are to control and direct the car and to give a smooth surface along which it may run, and to provide a surface and a structure upon which emergency safety devices may operate.

2 MATERIAL

(*a*) *Wood Guide Rails.*

30 There are still some wood guide rails in use for general-purpose elevators. Their use is justified in chemical and explosive plants where metal rails may create an explosion hazard or where certain corrosive atmospheres are encountered.

31 Unless wood rails are straight-grained, sound, and of approximately the same density, they may give very erratic stops when the safety applies. If the wood contains cross grain, checks, or similar defects, is badly worn, or has become rotted or spongy, the safety may fail to hold. Where wood rails are used, they should be inspected frequently and kept lubricated with tallow or linseed oil. Any rail damaged by the setting of the safety must be replaced promptly.

(*b*) *Steel Guide Rails.*

32 Steel rails are generally used today. They should be kept clean and free from solid lubricants to offer a good surface for the application of safeties.

3 RAIL FASTENINGS

33 During a safety stop, the guide rails must carry a load greater than the weight of the car, contract load, and various ropes and cables. All rail fastenings should be checked for tightness at regular intervals and after all safety tests.

4 EFFECT OF BUILDING SETTLEMENT

34 Buildings settle, and this may cause a bowing, or springing, of the elevator guide rails, in which case they should be realigned by competent elevator mechanics.

5 MAINTENANCE OF RAIL SURFACES

35 Lubrication should be furnished on the rail surface to reduce friction and wear between guide shoes and rails. They will in time, with proper lubrication, wear to and maintain a smooth surface and give satisfactory operation for many years. If rail surfaces become gummy, they should be cleaned and relubricated. If there is an accumulation of old lubricant and dirt, the entire machined surface should be cleaned. (See also Par. 18.) This may be done with a high-flash-point solvent, unless this coating has been accumulating over a period of years, in which case mechanical means may be necessary for removing it. Roller guides with rubber-tired wheels should operate on dry rails.

6 INSPECTION OF RAILS AFTER SETTING OF SAFETY

36 After a safety has set, the guide-rail surfaces should be thoroughly inspected to make sure that the surface of the guide rail has not been roughened unduly and that none of the fastenings have been loosened. If the surface of the rail has been cut or torn, it should be rubbed down with an abrasive block or a rail file. This smoothing of the surface should not be carried to the point that the marks are entirely eliminated, as the rail thickness may be decreased too much. With wedge-clamp safeties, variations in rail thickness produce violent fluctuations in retardation. If any rail fastenings are loose, see that they are tightened before the elevator is again put in service. For maximum service and safety, maintain rails in good condition.

IV BUFFERS

1 TYPES

37 Buffers are of two types, either oil or spring.

2 IMPORTANCE OF PROPER OIL IN BUFFERS

38 Because the flow of oil varies with viscosity, it is important to use an oil of the same viscosity as that provided by the manufacturer for the original filling. The use of a heavier or lighter oil will seriously affect the buffer action. The oil used should be 100 per cent mineral and free from acid.

3 IMPORTANCE OF PROPER OIL LEVEL

39 The piston must operate in oil during the entire stroke; therefore it is vitally important that the oil level be maintained. All buffers will show a gradual decrease in oil level due to their use and slow evaporation of the oil in the buffer. The oil level should be checked at each inspection, and oil of the proper grade to maintain the original viscosity should be added when necessary.

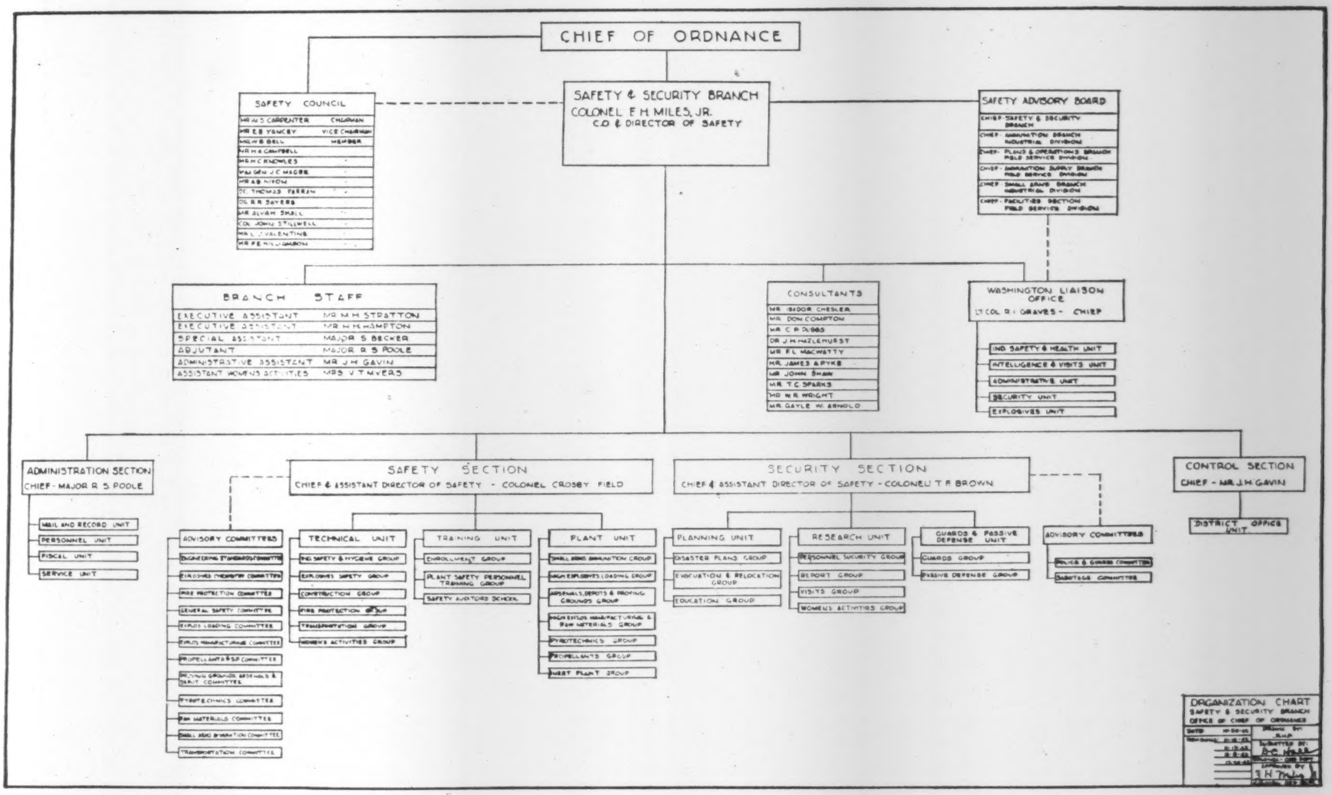
4 ALIGNMENT OF BUFFER

40 The buffer plunger as originally installed is substantially vertical. This alignment should be checked occasionally. If found to be out of plumb, it should be realigned.

5 ANCHORAGE

41 The bolts holding the buffer in the pit should be checked to be sure that they have not become loosened. Where pits are

(*Continued on page 359*)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SAFETY COUNCIL
MR W S CARPENTER CHAIRMAN
MR E B YANCEY VICE CHAIRMAN
MR W B BELL MEMBER
MR H A CAMPBELL
MR H C KNOWLES
MAJ GEN J C MAGEE
MR A B NIXON
DR THOMAS PARRAN
DR R R SAYERS
MR ALVAH SMALL
COL JOHN STILLWELL
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CHIEF - PLANS & OPERATIONS BRANCH FIELD SERVICE DIVISION
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ADMINISTRATIVE UNIT
SECURITY UNIT
EXPLOSIVES UNIT
ADMINISTRATION SECTION
CHIEF - MAJOR R S POOLE
MAIL AND RECORD UNIT
PERSONNEL UNIT
FISCAL UNIT
SERVICE UNIT
SAFETY SECTION
CHIEF & ASSISTANT DIRECTOR OF SAFETY - COLONEL CROSBY FIELD
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ENGINEERING STANDARDS COMMITTEE
EXPLOSIVES CHEMISTRY COMMITTEE
FIRE PROTECTION COMMITTEE
GENERAL SAFETY COMMITTEE
EXPLOS LOADING COMMITTEE
EXPLOS MANUFACTURING COMMITTEE
PROPELLANTS & SP COMMITTEE
PROVING GROUNDS ARSENALS & DEPOT COMMITTEE
PYROTECHNICS COMMITTEE
RAW MATERIALS COMMITTEE
SMALL ARMS AMMUNITION COMMITTEE
TRANSPORTATION COMMITTEE
TECHNICAL UNIT
IND SAFETY & HYGIENE GROUP
EXPLOSIVES SAFETY GROUP
CONSTRUCTION GROUP
FIRE PROTECTION GROUP
TRANSPORTATION GROUP
WOMENS ACTIVITIES GROUP
TRAINING UNIT
ENROLLMENT GROUP
PLANT SAFETY PERSONNEL TRAINING GROUP
SAFETY AUDITORS SCHOOL
PLANT UNIT
SMALL ARMS AMMUNITION GROUP
HIGH EXPLOSIVES LOADING GROUP
ARSENALS, DEPOTS & PROVING GROUNDS GROUP
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DISTRICT OFFICE UNIT
ORGANIZATION CHART
SAFETY & SECURITY BRANCH
OFFICE OF CHIEF OF ORDNANCE

SAFETY *in* ARMY ORDNANCE ESTABLISHMENTS

By COLONEL CROSBY FIELD

ASSISTANT DIRECTOR OF SAFETY, ORDNANCE DEPARTMENT, CHICAGO, ILL.

REALIZING long before the public the need for overcoming the handicaps to production created by the occurrence of the large number of industrial accidents, Major General Levin H. Campbell, Jr., immediately after his appointment as Chief of Ordnance, U. S. Army, established the Safety and Security Branch (originally known as the Explosives Safety Branch). In the first order establishing this branch, it was charged with taking "the steps necessary to insure the safety and security of specific plants, facilities, and installations assigned to the Chief of Ordnance in which explosives, propellants, or their ingredients are manufactured, processed, or stored."

The present organization of the Safety and Security Branch is shown herewith. As will be noted from this chart, the principal work of the branch in connection with the plants is performed by two sections, the Safety Section and the Security Section.

For the purposes of the mission of the Safety and Security Branch, "safety" may be defined as the determination of the hazards inherent in the processes, equipment, machinery, buildings, and areas, and the development and adoption of a proper protective procedure either to eliminate these hazards or, if they cannot be eliminated, to reduce their effects. "Security," on the other hand, is the determination of the hazards to the plant or to the production of the plant, which hazards are planned by some agency bent on mischief.

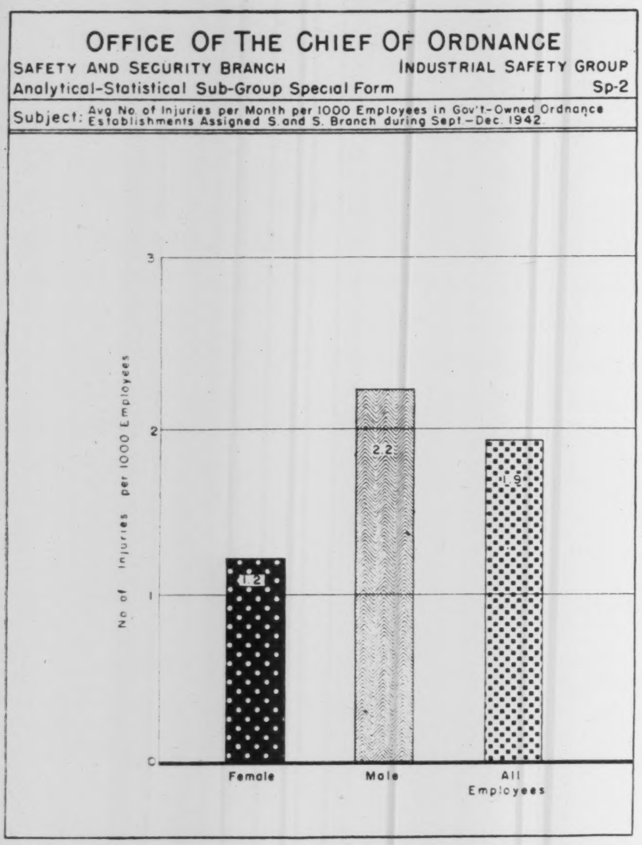
Safety is, therefore, largely a matter of things or materials; security is largely a matter of personnel. Safety is protection against hazards that originate inside the plant or storage area; security is protection against hazards that originate in sources outside the plant although, of course, their effect is felt inside the plant.

Hazards to safety are largely inanimate in origin; hazards to security are animate and arise by intent.

Referring now more particularly to the Safety Section, it may be stated that its principal objective is to develop and have adopted by the operating management of a plant proper protective procedure against the hazards which have been discovered in each operation. This includes inspection of the design of buildings, equipment, and their layout; their method of operation including maintenance; selection, training, and supervision, from a safety viewpoint, of the personnel necessary to the operations; maintenance and inspection of plant for equipment and the handling and storage of the products, their components, and ingredients. This further requires frequent inspections to insure that the developments thus arrived at are continued in effect.

The accompanying illustrations, which are self-explanatory,

Contributed by the Production Engineering Division and presented at the Spring Meeting, Davenport, Iowa, April 26–28, 1943, of The American Society of Mechanical Engineers.



indicate the trend of accidents in the various types of plants which are the continuing inspection responsibility of the Safety and Security Branch. It is gratifying to note the downward trend in the various types of plants and to note further that, on the whole, the ordnance establishments, in frequency and severity, have rates lower than corresponding commercial plants.

Another interesting fact, demonstrated by the illustrations, is that the frequency for accidents in all ordnance plants arising from explosions is approximately $^1/_{20}$ of the frequency for accidents of all types.

DUTIES OF THE SAFETY SECTION

The duties of the Safety Section may be summarized as follows:

1 To handle all matters pertaining to the safety, fire protection, and industrial hygiene of government and commercial establishments assigned to the Ordnance Department for continuing inspection responsibility.

2 To prepare, revise, and distribute the Safety Digest, the Safety Digest Supplement, the Ordnance Department Industrial Safety and the Industrial Hygiene Manuals and Bulletins, and other memorandums modifying these.

3 To prepare, revise, and distribute the safety rules and regulations of the Ordnance Department, including the Ordnance Safety Manual and Safety Bulletins.

4 To compile, analyze, and disseminate pertinent statistics on accidents and other causes of absenteeism.

5 To develop and disseminate standards of safety and industrial hygiene.

6 To investigate and report upon all fires, explosions, and other unusual occurrences in which explosives are involved and to recommend preventive measures.

7 To make regular and frequent safety audits of all establishments assigned to the Ordnance Department for continuing inspection responsibility.

8 To approve, from a standpoint of safety, all new construction, alterations, and equipment for the manufacture, processing, handling, and storage of military explosives and ammunition, and their ingredients and components.

9 To give technical advice on all Ordnance Department safety, fire-prevention, and industrial-hygiene matters.

10 To supervise the enforcement of safety recommendations by the Service Commands in establishments in which the Ordnance Department has a substantial interest or contract.

11 To develop and administer a program of employee training in safety, fire prevention, and industrial hygiene in ordnance plants, and to supervise its enforcement.

12 To develop and analyze schools for the training of Safety Section officers and safety auditors.

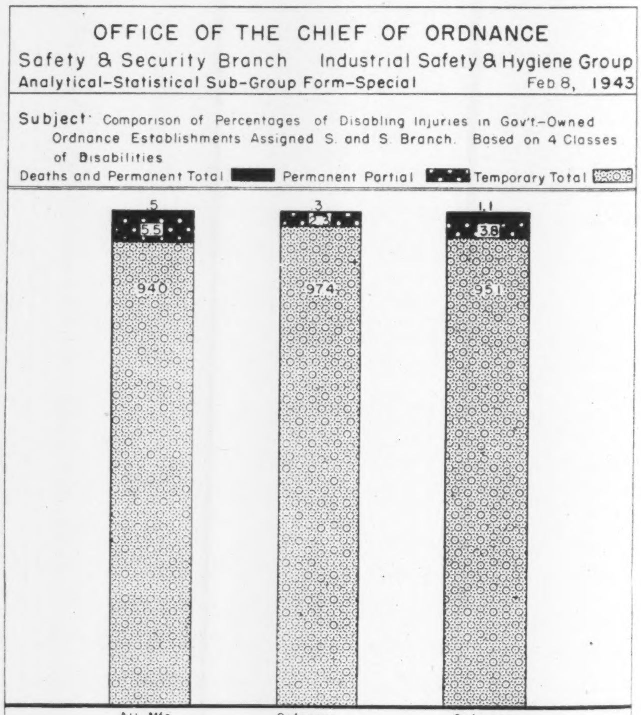
13 To collaborate with the Insurance Section and other branches of the Ordnance Department on safety, fire prevention, and industrial health.

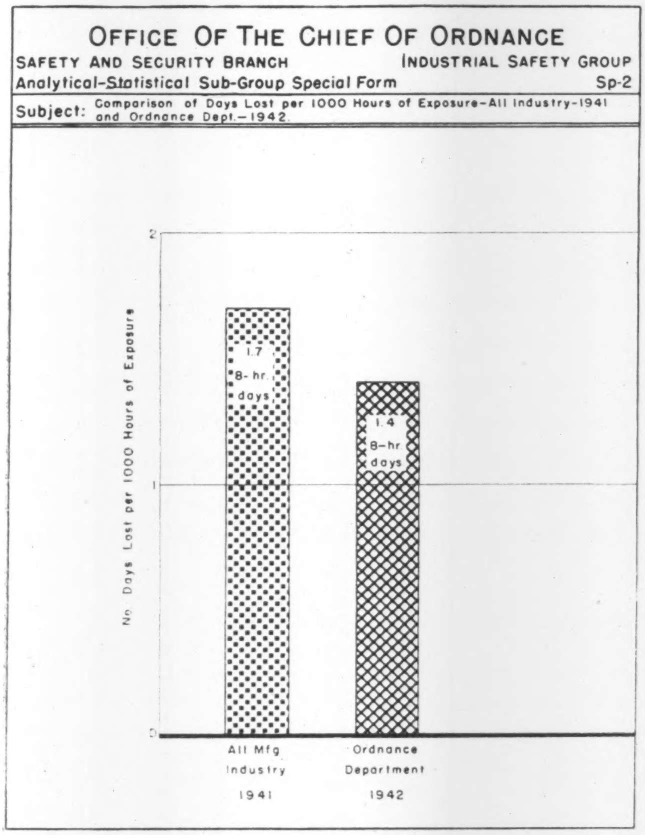
In its work the Safety Section has to maintain intimate contact with representatives of four large groups of people which include the following:

1 Experts of the various industries, in which industries the Safety Section must function. Representatives of these industries have been placed on advisory committees of the Safety Section, thus forming what might be called an advisory unit.

2 Sources of information, regarding hazards and the proper protection against such hazards, may be within the Ordnance Department or other federal agencies, or may be other organizations. In order to maintain these contacts and to develop its own standards, a technical unit has been formed in the Safety Section. The technical unit has no connection directly with any operating plants but has with all other agencies.

3 In order that a channel may be provided for communications to and from plants, and in order that safety in those plants may be administered and followed up, a plant unit has been formed in the Safety Section. All plants in which this branch has continuing inspection responsibility have been assigned to one or the other of the groups in the plant unit, and the chief of a plant-unit group is charged with seeing to it that the plants





in his assignment are properly serviced and safety-audited, and that recommendations are carried out, utilizing the proper organization channels therefor.

4 A training unit has been formed.

The allocation of the plants according to groups naturally is related to the type of manufacture or operation encountered, those plants having similar operations being grouped together. The chief of the plant-unit group is automatically the secretary of the advisory unit committee of experts from the industry in which his group operates, so that there is a very close tie-in between the experts of the industry and the group chief, his auditors actually making the safety inspections. This intimate relationship has been of great assistance in determining the basis for acceptable standards, and then in their formulation. Furthermore, through the close co-operation which thus exists between representatives of industry and the chiefs of the various plant-unit groups, efforts have been made to bring substandard plants up to the safety level attained by the better plants in the industry.

TRAINING SCHOOL FOR SAFETY AUDITORS

One of the major difficulties in the establishment of this section has been to obtain properly qualified personnel. It soon became apparent that such were not obtainable without a course of training, and therefore a training unit was set up. This training unit not only has enrolled the necessary personnel and then trained them as well but has also provided training courses to which contractors operating plants, ordnance districts, and others interested, have sent men to be trained.

The primary function of the school for safety auditors is to train the Safety Section's own staff at headquarters, its representatives at the district offices, and in particular its safety auditors (or inspectors). It was soon discovered that, although there were men available with some fire-protection experience and knowledge, or with some industrial-safety experience or knowledge, there were very few available having sufficient of either or both types of qualifications, together with a knowledge of explosives, to enable them to undertake the work of the Safety Section in any of its particular functions. It became necessary, therefore, to train these new employees, and the School for Safety Auditors was started, the seventh session of which is now in operation.

Immediately upon moving to headquarters in Chicago in July, 1942, the Illinois Institute of Technology, the Underwriters' Laboratories, the National Safety Council, the Crime Detection Laboratory of the Chicago Police Department, the Chicago Fire Department, several of the insurance companies, rating bureas, etc. were requested to join in the establishment of the school. Their response was remarkable and on August 3, 1942, the first School for Safety Auditors in Explosives Plants was started with twenty-one students and a highly concentrated six weeks' course.

The purpose of the course was to impart to selected members of the Explosives Safety Branch, Office of the Chief of Ordnance (now the Safety and Security Branch), knowledge of the hazards involved in manufacturing, handling, and storing explosives, and of the methods available for preventing accidents in these activities, as well as of minimizing the effects of such accidents should they occur.

Subjects included in the Explosives Safety Branch School, in addition to lectures given by officers of the branch on specialties and a daily hourly catechism on the Ordnance Safety Manual, are as follows:

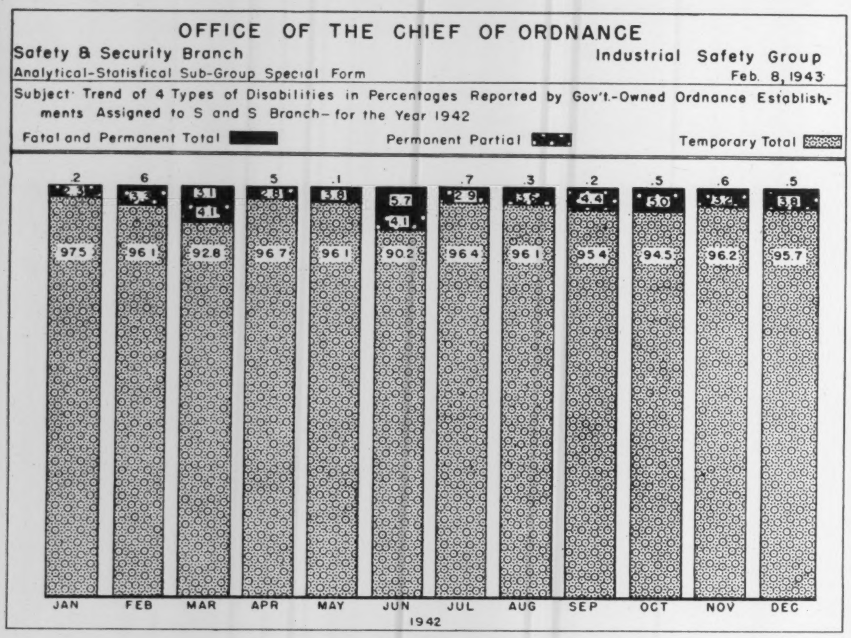
	Total	—Scheduled—	
Name	class hours	Lab	or Field
E.S.B. procedures	24	..	..
Explosives	36	..	8
Fire-protection engineering	42	18	..
Accident prevention is divided into:			
Explosives safety	30	..	8
Industrial safety	48	16	..
Occupational diseases	6	..	..
Safety inspections	...	..	16
Personnel and training	36	..	..
	222	34	32

In the third school, which started October 5, 1942, women helpers, known as "safety-auditor aides," were enrolled, with the idea of endeavoring to develop women if possible as assistants to the safety auditors. After a period of putting their training into practice, these aides should accomplish a reduction in the work to be done by the safety auditors themselves and, at the same time, retain their long experience for supervision.

Qualified women for this type of work are very scarce and none have been found available for the more responsible work of the safety auditor himself. In an attempt to meet this situation, the fourth class in the School for Safety Auditors has had included among its members four women of general engineering training. In addition thereto, another course of six weeks was arranged with the Illinois Institute of Technology, as a preliminary safety-engineering course, and fourteen women enrolled in this latter course. Upon graduating from this course, they entered the regular School for Safety Auditors so that after approximately thirteen weeks of training, we have women safety-auditor aides qualified to take over a much greater part of the work at present performed by the safety auditors. The complete replacement of men safety auditors by women does not at this time appear to be practicable.

SCOPE OF SAFETY SECTION DUTIES

One of the principal duties of the Safety Section is the inspection of plants. The government-owned government-operated and government-owned contractor-operated plants are surveyed solely by safety auditors of the headquarters office of the Safety and Security Branch. These men are called safety auditors rather than inspectors, as their function is not only to inspect or survey, but also to evaluate conditions in a plant in terms of



safety and to discuss them with management and educate by recommendations.

Industrial hygiene in plants assigned to this branch has been a matter of great concern. Thanks to the assignment by the Surgeon General, U. S. Public Health Service, to the Safety Section of two commissioned officers, representing the United States Public Health Service, and by the Surgeon General, U. S. Army, of one commissioned officer, representing the Surgeon General of the United States Army, proper attention is being paid to this factor under their auspices.

In addition to providing the answer to numerous questions which arise daily in connection with industrial hygiene, developments are in progress which have to do with the prevention and the cure of toxic effects. Industrial-hygiene surveys have been made of many plants.

One of the developments of the Safety Section has been the prompt abstracting of all reports of explosions or investigations thereof and recommendations for prevention. These abstracts together with comments of experts are forwarded to all plants which might be similarly affected.

Another important function of this section has been to develop proper safety clothing for both men and women. Although a great deal has been accomplished in this to date, it is felt that this must be a continuing effort and will not be completed for some time.

Liaison has been maintained with federal, state, and local authorities having special connection with industrial safety and hygiene and, in addition thereto, with the insurance unit in the fiscal unit of the Ordnance Department, in order to secure the co-operation of the casualty-insurance carriers on assigned plants.

A library of safety has been established which includes not only the practical safety plans and publications of the principal explosives plants but also a technical reference file.

A standard procedure for investigating and reporting industrial accidents in ordnance establishments (based on American Standards Association procedure) has been developed through the use of directives, visits, correspondence, and conferences.

A machine-tabulating unit has been developed so that individual injury reports can be coded for outstanding factors. This enables speedy compilation into various tables and studies of causes, contributing factors, and other pertinent information.

What is perhaps the most effective single effort in achieving safety in plants is the training of plant personnel in industrial safety and industrial hygiene. By plant personnel is meant the employees of the contractor who are actually doing the protection work in the plant. The first course of training for foremen and employees in industrial safety and hygiene has been developed and, with well-qualified teachers, is now at work in the field. An extensive study is being made of methods of job-instruction training as a method for accomplishing this purpose, and contacts have been made with federal agencies engaged in similar work. The plan includes necessary re-education of workers in safety methods, and also necessary follow-up to complete safe practices in the foremen's and employees' minds. The plans include development of necessary tests, cause-analysis tables, job analysis, and the like. Special courses are being developed to meet the needs of the various establishments where the training program is to be administered. Collaboration with the civilian personnel division is an important part of this work.

It might be said that the aim of this branch is to make "safety-minded" every person connected with an ordnance establishment, from the contractor's president to the clean-up porter, including that most important person, the foreman. We would go one step further, and try to have each person be not only safety-minded, but to make a habit of safety; may we coin the expression "safety-habited?" Our aim, therefore, is to make each person safety-habited.

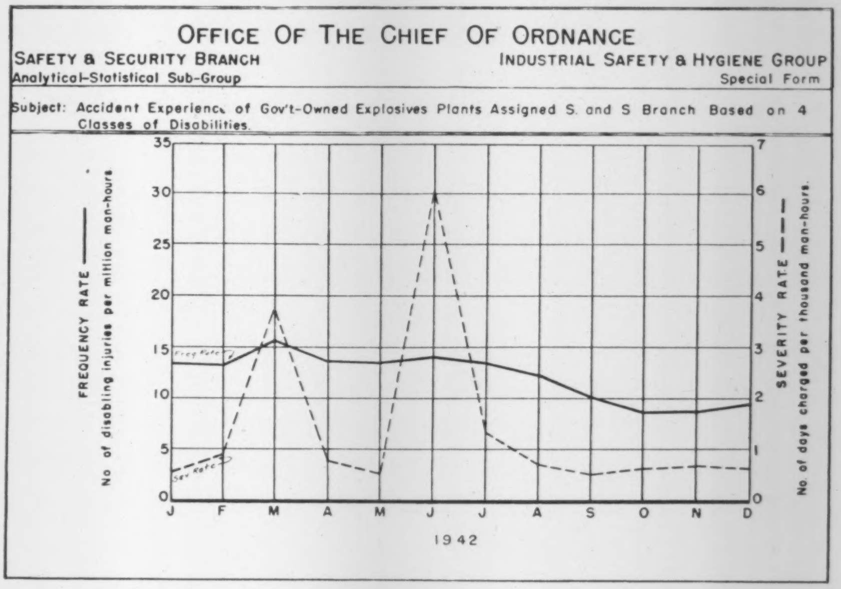
The work of the Security Section is similar to that of the Safety Section in that its organization is such as to provide liaison with representatives of all the various groups with which the Security Section has to maintain close contact. Among the many functions which the Security Section has to perform may be mentioned supervision of investigative systems for prospective employees; control of aliens, criminals, and visitors; dissemination of morale-building information including distribution (but not production) of posters advocating safety, security, and morale; awards of merit for extraordinary acts of morale; and other things, such as marksmanship of guards; co-operation in the publishing of plant organs, in so far as safety and security are concerned; and the open and undercover control of subversive and criminal activities. It further includes the dissemination of morale, safety, and security information to the local press, essential to the development of the morale and co-operation of the community; the development of disaster-plan procedures and reports on disasters; and evacuation and relocation plans.

ORGANIZATION SETUP OF SAFETY AND SECURITY BRANCH

For the selection of a chief of the Safety and Security Branch who would be the Director of Safety for the Ordnance Department, the Chief of Ordnance was most fortunate in having available for this assignment Col. F. H. Miles, Jr., an Ordnance officer not only well known for his complete technical and practical knowledge of military explosives, but also a man who has been well trained in industry. He was also most fortunate in having outstanding and distinguished representatives of industry accept appointments on the Safety and Security Branch Safety Council, which also includes the Surgeon General, U. S. Army; the Surgeon General, U. S. Public Health Service; the Commissioner of Police, New York City; the Director of the Bureau of Mines and the Assistant Chief Inspector, Bureau of Explosives; and the Association of American Railroads. These men have unselfishly devoted considerable time in their meetings and in other activities to the work of this branch and have set the broad general policies on which the branch is operated. They have further reviewed the activities and achievements of the branch periodically and have guided the selection of its objectives as well as its methods and procedures.

A word of acknowledgment and thanks must be given not only to the members of the Safety Council but also to those well-known industrialists and technical men who have sat on the advisory committees, and who have acted as special consultants. These men, serving without remuneration and at quite considerable personal expense, have unselfishly devoted their time and great ability to assisting the branch in many ways.

Without the help of those who have been mentioned, and the continued cooperation of all officers of the Ordnance Department, other governmental agencies, insurance companies, and American citizens in general who are interested in safety, accomplishment along these lines would have been impossible.



In its program, the Safety and Security Branch recognizes certain fundamentals. While these are generally parallel to many usual industrial-safety activities, there are certain items which required specific attention, including the following: Plant location, housekeeping, fire protection, protective clothing, handling and transportation of explosives, employee population proportionate to operations, quantity-distance relationship, destruction of scrap or reject material, first-aid and medical facilities, change houses, and the enforcement of safety regulations.

SAFETY REQUIREMENTS OF PLANT FOR MANUFACTURE OF EXPLOSIVES

While in some instances, it is necessary to utilize existing industrial facilities, in general, a plant for the manufacture of explosives or the loading of ammunition should be located in a sparsely settled section of the country where there is sufficient space to permit the erection of manufacturing lines and buildings in accordance with established safety procedure. A flat terrain is preferable but a certain amount of rolling country can be utilized. Obviously, level country provides ease of installation of highways and railroad equipment and facilitates economic transportation of raw materials and products. Due consideration must be given to a good source of water supply, not only for manufacturing purposes, but to provide adequate fire protection.

The best means of fire protection is to build a plant of fire-resistant materials throughout. Important material should be safeguarded from fire loss by subdivision. Wherever possible, storage of essential material, equipment, and finished goods should be so arranged that no single fire or accident can destroy all available units of any particular item. This may be accomplished by the erection of storage units in various locations remote from each other or by separate storage in a single building provided with standard fire walls having properly protected openings. Large single areas should be avoided. Substantial physical barriers or complete fire-wall cutoffs should be installed, dividing large areas into separate manufacturing operations, thus limiting the spread of fire even under the most adverse conditions. Such cutoffs should always be constructed between floors.

Primary and secondary fire protection is required. First-aid fire-fighting equipment, such as fire pails and water barrels, extinguishers, and small hose are valuable during working hours in the hands of capable fire brigades if used promptly and with good judgment on incipient fires. Foam-type extinguishers are recommended for use near inflammable liquids, while carbon-dioxide extinguishers should be available for use on electrical fires or where delicate and valuable equipment may be damaged by the use of other types of extinguishers. Extinguishers must be kept full and in good working order. It is desirable to seal extinguishers to prevent malicious tampering. When a plant is of sufficient size, the plant fire brigade should be augmented by a full-time fire department under competent supervision and suitably equipped with powered pumpers and hose trucks.

No fire-protective system is better than its water supply. The entire premises should be covered by a looped or gridded system of fire mains with hydrants and shutoffs. If a municipal or public water system is relied upon, service connections must be of sufficient capacity and should be augmented by the installation of gravity tanks, fire pumps, and private reservoirs. Duplicate sources of private water supply are recommended.

Wherever the material being handled will permit, automatic sprinkler systems should be installed, as these when installed, on the basis of past experience, have held under control at least 98 per cent of all fires. No other single fire-protection device has done so much to reduce interruption of production caused by fire.

Contact with public fire-alarm systems and with adjacent public fire departments is important. The chief of the public fire department should be brought to the plant and given an opportunity to become familiar with the private fire-protective system, so if a fire occurs he will know exactly what plan to follow.

FUNDAMENTAL PLANT-SAFETY PRINCIPLES

The correct number of workers to populate any given operation must be established. Anxiety to complete a production program should never excuse crowding. The first fundamental principle of safety in an explosive plant is to expose the least number of employees to the least amount of explosive consistent with economic and continuous operation. Once the relation between maximum number of workers and the correct amount of explosive has been established, it should be posted in the workroom or area and then enforced. No deviation from this rule should be countenanced.

In a plant layout, it is essential to establish a relationship between the amount of explosive being used in an area and the permissible distance to any adjacent area. This quantity-distance requirement must be recognized when the plant is constructed. Certain tables have been developed, based on comprehensive tests at proving grounds and on the actual records of fires and explosions involving explosives and ammunition. The tables established, pertaining to each particular class of ammunition or explosives, recognize the possibility of a hazardous fire during manufacturing, processing, or handling; the destruction from sympathetic detonations, the hazards from flying missiles projected either as pieces of broken containers or complete rounds of ammunition, and the effects of the concussion produced by the detonation of a quantity of explosives. The possibility of structural damage to inhabited buildings, railroad equipment, automotive equipment, and the injury of persons located at any point external to the plant itself has been considered. In addition, the same relationship has been studied and developed, covering the permissible amount of explosives to be handled within any plant operations or line and the distance to any factory building within the same manufacturing line or area. The use of these quantity-distance tables has had much to do with the good record produced by the explosive industry.

HAZARDS OF HANDLING AND TRANSPORTING EXPLOSIVES

Safety in the handling and transportation of explosives or ammunition includes the handling of the least significant primer to the final transportation of the largest bomb. Each individual explosive, component, or final product entails a different safety procedure which must be developed, based on knowledge of the inherent hazards as well as the method of production. In general, quantities should be held to the absolute process minimum where hand or hand-truck transportation is involved. Plant layouts must be such that workers have sufficient space in which to function. An example of this recently occurred where the permission to allow two workers to work in a space normally designed for one was a contributing factor to a major disaster. The rough handling by workers of any explosive must not be permitted. Trays, tote boxes, and other containers must always be kept in good order and the components or materials handled should be supported or so packed that they will not strike against each other. Containers of hazardous material or loaded components must not be dragged, dropped, or thrown about but must be lifted or trucked.

When locomotive or automotive equipment is used for transportation, it must be of a type suitable for such work. Locomotives must be of such type that they cannot set or communicate fire. Locomotives should not remain in front of buildings containing hazardous materials. When necessary to spot cars for loading and unloading, the doors to such buildings should be closed when the locomotive is passing. All railroad cars, trucks, and any other vehicle used in the transportation of hazardous or explosive materials should be so constructed that no part of the load can fall off. Motor trucks and other carriers should have wood floors and sides only. Automotive equipment, used in the transportation of explosives or loaded ammunition, must be kept continuously in good operating condition, particularly as to brakes, tail gates, fuel leaks, etc., and frequent inspections, preferably daily, should be made of each vehicle to insure it is constantly ready for safe operation. Any truck or vehicle loaded with hazardous material should never be left unguarded.

When manufacturing or handling includes intimate or personal exposure to explosives or other similar hazardous materials, special clothing should be furnished employees. Safety uniforms or special clothing should always be worn when required and should be of a type having no metal buttons, no pockets, other than a skeleton pocket and should be of a hard-surfaced close-woven material. When such safety uniforms are used, a complete change of clothing is recommended so that street clothes will not be worn at work, and the clothes which have been exposed to the hazardous material will not be taken from the plant. Special conditions around operations where fine explosive dust is generated, or where exposure to hazardous vapors may require special footwear and the personnel exposed must wear shoes with conductive soles to permit the grounding of the static charges developed by the body. In such hazardous areas, all floors should be of so-called conductive type, having an extremely low electrical resistance to ground, and should be suitably grounded at several points.

As in any other type of manufacturing establishment, it holds true in an explosive plant that good housekeeping is a fundamental and important principle of accident or fire prevention. General good order and neatness can do much to reduce the number of accidents and personal injuries, will permit pride in the place of employment, and will result in a better product. "A place for everything and everything in its place" is a much better program and an easier one to follow than periodic cleanups. Good housekeeping practices should not be confined to manufacturing areas alone. It is equally essential outside of manufacturing areas. Rubbish, dry grass, and other forms of waste must never be permitted to accumulate in outside areas where it may produce an exposure to the plant if a fire occurs in such materials.

Closely allied with good housekeeping is sanitation, the lack of which in any establishment may affect the alertness of the workers. Frequently, accidents may be traced to unfit conditions, and to unwholesome and unhygienic practices, not only in the plant but in the home. Adequate change houses are recommended where the changing of clothing can be facilitated, where proper use of sanitary features can be supervised, and where personnel cleanliness may be required or insisted upon.

Industrial wastes require separate disposal. Waste water from a laundry where explosive operators' clothing is washed or other waste water containing explosives must run through settling tanks or pits to remove the explosive before it creates a hazard by settling out or by the contamination of the soil or other water.

It is important that a suitable burning ground, disposal or destruction area be established. All material from cleanup operations and all rejected product should be destroyed at this area which by its isolated location removes the hazard from other areas. The disposal of all waste material should be under the control of a competent employee thoroughly familiar with the inherent hazards.

A comprehensive plan for medical control is essential. Obviously, this plan must be based on the number of persons employed and should be varied when necessary to make positive that adequate medical control is established. If needed, a complete plant hospital should be provided and should be in the charge of a competent physician. Dressing stations should be located at strategic points within or near explosives areas, key personnel should be trained in the use of first-aid materials, and contact relations should be made with outside emergency facilities such as hospitals, ambulance services, auxiliary corps, and with additional medical assistance in the event a catastrophe demands additional help. In every plant, emergency and rescue squads should be selected from each shift personnel and trained. These squads should receive regular instruction from the medical director and should participate in simulated emergency-training demonstrations to become familiar with emergency technique which might be required in any operating area.

ENFORCING THE SAFETY PROGRAM

While it has been stated that the safety program of an explosive plant is fundamentally no different from a similar program in a nonexplosive endeavor, yet it can fail to attain its objective if it does not include some means of enforcing the safety instructions and regulations. The mere formulation of safety rules, the development and construction of a plant complying with all known safety practices, the provision of proper safety clothing and sanitary facilities, the maintenance of good manufacturing procedure cannot hold to a minimum injuries and cases of industrial disease unless there is established at the same time a very definite program of enforcement. A large plant may warrant the establishment of a safety department in charge of an industrial-safety engineer. A smaller plant may require that the safety program be carried on solely by foremen, but many plants may require that an employer-employee combination work on this important problem so that the compliance with safe-practice rules will be as well established as compliance with the rules and instructions relating to the quality of the manufactured product. The responsibility for such activity is not confined to the supervisory personnel but must include the education and supervision of every worker.

Safety committees and foremen's committees should be organized, accident causes should be developed, based on adequate and complete investigation of any injuries or similar occurrences, and, from such statistical data, practical operating rules established. It is essential that a sense of responsibility be developed so every individual will realize any act on his part, not consonant with good procedure, may create the setting for an accident which will not only injure him but his associates and, at the same time, may interfere with our war effort. The foreman is undoubtedly the keyman. He must first become not only "safety-minded," but "safety-habited;" then all the workers reporting to him, in following his example, will become safety-habited.

Diesel Road Locomotives

(*Continued from page 338*)

when made of steel, about 2 lb per gal. Aluminum tanks weighing 1 lb per gal have given satisfactory service in railroad operation. Diesel road locomotives provide tanks for these supplies with a combined capacity of 1 gal per engine hp. By making the tanks in aluminum, 1 lb per gal could be saved or a total of 5250 lb for the 5250-hp *B* locomotive.

The aluminum sheet, structural shapes, and deck used on the Pennsylvania P5-A locomotives saved 32,000 lb per locomotive. A similar application could be made on locomotive *B* and would more than meet the requirement of 8750 lb remaining.

SPACE SAVING A FEATURE OF SMALL-BORE ENGINES

Another productive source for weight saving could be realized by so arranging the Diesel engines and generators to take advantage of the reduced engine-space requirements of small-bore engines. If full advantage could be taken of this space saving, the engine compartment could be made one half the length needed for the large-engine installation. This might easily result in savings of an additional 100,000 to 125,000 lb not included in the original comparison. The improvement in performance resulting from such a saving should be an incentive for a careful analysis and vigorous attempt to accomplish this result. It is obvious that weight saving by complete elimination of material not only does not add to the cost of any product but actually reduces it. Engineering along these lines pays large premiums and can make the final economic picture so attractive that new applications are justified and replacement of existing equipment may be desirable.

In summarizing, the following facts are evident:

1 Weight saving in the locomotive improves all of its operating characteristics, except the advantage of high tractive effort at starting and for speeds up to about 20 mph.

2 The greatest single weight saving can be made in the engine and can be accomplished by reduction in bore, increased rating, and by the use of light materials of construction.

3 The use of small-bore engines and suitable arrangement of these engines can reduce the length of the locomotive and by that token result in additional weight reduction.

No analysis has been made of the possibilities of saving weight in the electrical equipment, air-brake equipment, trucks and axles, and the locomotive frame. Unquestionably, the use of aluminum alloys as well as other material developments and design improvements would produce weight saving in those parts. The road locomotive of the future can best serve its destiny by being designed to use all of the available weight- and space-saving methods that can be conceived. If it results in such light weight that starting tractive efforts is insufficient for satisfactory train performance, ballast at a few dollars a ton will always be available.

Machine Design—Lubrication

(*Continued from page 349*)

CONCLUSION

Some of the fundamentals in the lubrication of the surfaces of machines in contact and motion have been presented and some of the practical effects of design on these conditions have been considered. Obviously, the subject is too broad to cover more than a portion of it in this discussion.

Designers, of course, attempt to keep unit pressures down to prevent excessive wear, but sometimes this is impossible even when the flooded system of lubrication is used, due to restricted space preventing larger contact areas. Also, operators sometimes subject their machines to loads for which they were not designed. Where these conditions exist, lubricants having special characteristics must be used to permit the machine to operate without too excessive wear.

We have outlined some facts concerning the formation, actions, and limitations of boundary films and full fluid films. From a practical viewpoint, it may be that this information will assist in the solution of some design or operating difficulties.

Elevator Mechanical Safety Appliances

(*Continued from page 352*)

located in the neighborhood of railroad tunnels, subways, etc., vibration may loosen these holding bolts. Where this occurs, lock washers should be provided.

6 CORROSION

42 Buffers should be protected against corrosion by painting the cylinder with a good grade of machine paint or enamel, and the plunger should be given an occasional coating of oil. If the plunger shows any rusting or pitting, it should be thoroughly cleaned with fine emery paper or cloth (care being taken not to let abrasive dust fall into the openings in the buffer) and then be coated with oil. After the car has compressed the buffer, an inspection should be made to ascertain that the plunger has returned to the fully extended position.

7 FLOODING

43 Whenever the buffer has been submerged, as a result of a flood or pit leakage, the pit must be thoroughly drained, the oil buffer emptied, cleaned, and refilled with fresh oil of proper viscosity. The cleaning and refilling of the buffer should be done by the manufacturer, as most buffers are provided with very powerful return springs which may cause serious accidents to persons attempting to dismantle them unless they are quite familiar with their construction and are provided with suitable tools or equipment. Cleaning and refilling must be done before the elevator is again placed in operation.

8 SPRING-BUFFER INSPECTION

44 Spring buffers should be checked frequently to see that they are in correct vertical alignment without lateral support and properly seated in the cup or on the mounting provided. The supports of spring buffers must permit the spring coils to be fully compressed. Following the operation of spring buffers, they should be examined carefully to make sure that they have not been deformed or have taken a permanent set.

WHEN THE WAR ENDS[1]

By PAUL A. SAMUELSON

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

IN a university where students were ruthlessly eliminated at the end of the freshman year, it was the annual custom for one old professor to begin his lectures with the remark: "Gentlemen, take a careful look at the man on your right; now look at the man on your left. Remember their faces well, because next year one of the three of you will not be here."

Engineers and professional people must have a similar feeling about discussions of postwar unemployment. Remembering that more than one half of all civil engineers were completely unemployed in March, 1933, that annual earnings of hired and self-employed consulting engineers had dropped tremendously, they have a natural and genuine interest in postwar problems. If each thinks of his two best friends in the profession, and then faces the future honestly without wishful thinking, he must admit that at least one of the triumvirate will be destitute within a few years from now . . . unless our economy is very, very lucky, or very, very wise.

What is true for the engineering profession is in lesser or greater degree true for all. Everywhere men have cut their ties with the past. Old jobs have been left for new wartime positions, in or out of the armed services. Marriages have been entered upon blissfully, and throughout the land there is a bumper crop of babies. We are all of us riding a tiger. Incomes have risen, promotions have been granted. It is enough to live for the moment and to devote all of our energies to the primary objective of winning the war. But in the back of each person's mind is the insistent question that cannot be disregarded: After the war, what? How long can all this keep up?

For whom then is the new series of books by Stuart Chase[2] written? We may answer in John Donne's words: "And therefore never send to know for whom the *bell* tolls; it tolls for *thee*."

II

These books have been written as reports to the Twentieth Century Fund. This is a nonprofit foundation interested in the objective study of important economic problems. The late Wm. E. Filene, prominent Boston merchant and philanthropist, had a deep interest in the work of the foundation, and its present board of directors contains such prominent names as Dennison, Knauth, Biddle, Berle, Leeds, Myers, Taft, Bliven, Tweed, and many other prominent industrialists and men of affairs. These show, if indeed any testimony is needed, that the organization is not a radical one in any sense of the word.

The author of the book, Stuart Chase, is alone responsible for the conclusions stated. After attending the Massachusetts Institute of Technology and Harvard University, he was for many years a practicing accountant. Since 1925 he has published one good-sized book almost every year, ranging in titles from "The Tragedy of Waste," "Prosperity—Fact or Myth," "The Tyranny of Words," to the present series. In addition, he has published numerous articles in such journals of opinion as *Harpers*, the *Atlantic*, *Reader's Digest*, the old *Scribners*, and others. Like any free lancer whose living depends upon his pen, Mr. Chase writes well in a style that rarely fails to interest even where it does not convince.

It is his strength to have had an open and inquiring mind where social problems are concerned. The world has gone through many changes since the now mythical years of the twenties, and these events have left their impress on Chase's thinking. His belief, even in the halcyon days of the "New Era," that our best engineering knowledge would permit great increases in production if only an unlimited market could be guaranteed, prevented him from being taken in by the catch phrases of an unending prosperity. Not that he called the stock market crash in 1929 as to its exact appearance on that black October Tuesday; but at least it came as no surprise to him.

Throughout the years, despite increasing preoccupation with such matters as saving and investment, one element in Chase's thought has not changed. Now, as years ago, he tends to take what may be called the *engineering* point of view—that it is resources, technology, "know-how," and human needs which are the important things, and that money and finance are secondary. Today, the war is causing an increasing number of people to see things in their real, rather than financial, form. This is well illustrated in the following quotation from "The Road We Are Traveling."

> Congress before the attack on Pearl Harbor had already appropriated more than twice as much money for guns as the New Deal spent for butter, and other things, in eight years to 1940. It had appropriated more than twice as much as was spent for guns in the last war, when we shipped two million men to France. Where's the money coming from? Nobody gives a damn. That is just the point. In the old economy, such reckless outlays would have spelled bankruptcy and ruin. Money came first and men came second. In the new economy, no nation will permit bankruptcy and ruin so long as men, materials, and energy are available. Men first, money second.
>
> You do not understand how this can be so? I will try to explain. Germany does not permit ruin and bankruptcy and has little use for gold. It is Germany we are up against now. Adam Smith may heave in his grave, but no nation in this dangerous world of 1942 is meekly going bankrupt because some textbooks say it ought to. It will go physically bankrupt when it runs out of food, coal, iron, oil, aluminum, and not before. Well, who is going to pay for it? It is being paid for right now with the mental and physical work of those who are producing and moving the goods. "Stuff and nonsense," you cry, your eye on the book. Put your book away, my friend. The books which will explain the new world we are entering have not been written (pp. 50–51.)

That this feeling is spreading to all classes of society is shown by *Fortune's* quotation of one young man's sentiments: "I don't mind fighting if it is necessary. But I don't want to spend two or three years in the army and then come out only to be told by an aged idiot that I can't have a job until the budget is balanced." To which Chase adds: "There will be more than twenty million men from the army and the munitions industries feeling like that in 1944" (p. 101).

Because Chase represents a growing school of thought, intelligent conservatives with a sense of history will be interested in his viewpoint. They realize that the clock of time cannot be turned back, so that it is intelligent conservative policy to give gradually with the tide, rather than inflexibly stem the current until strains have so accumulated as to lead to buckling and breakdown. A prize fighter "rides with a punch" rather than meeting it head on. By a similar strategy of gradual reform, conserving what is good in the old but not turning one's back on the new, the thoughtful moderate can hope to avert cataclysmic, revolutionary change.

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[1] One of a series of reviews of current economic literature affecting engineering, prepared by members of the department of economics and social science, Massachusetts Institute of Technology, at the request of the Management Division of The American Society of Mechanical Engineers. Opinions expressed are those of the reviewer.

[2] Six small volumes are to be published under the general heading, "When the War Ends." Of these, the first two have already appeared under the titles, "The Road We Are Traveling, 1914–1942," and "Goals for America: A Budget of Our Needs and Resources." Four others, dealing with domestic and international financial problems, winning the peace, etc. are to be issued at few months' intervals.

III

Each of these books is slightly over 100 pages in length. "The Road We Are Traveling, 1914–1942," consists of five sections in all, the first two of which give a thumbnail historical sketch of the period since the beginning of the First World War. The author's depiction and interpretations of events well within the memory of every adult will be of the greatest interest to the general reader. Chase begins with a description of State Street, Boston's financial center in 1913, and follows through the impact upon it of the first war, the automobile, the palmy twenties, the Great Depression, the New Deal, and now again, a second World War.

It is human to push unpleasant memories out of the conscious mind. "When the Devil was sick, then the Devil a Saint would be, but when well . . . ." Today with wartime prosperity, we are beginning to forget the specter of unemployment which dogged our steps for a decade, and which still lurks in the background, ready to move in when the wartime Federal expenditures are curtailed. It is good therefore to read the author's account of how the prosperity of the golden twenties disappeared overnight, and how the Great Depression developed.

> Did the crash in Wall Street bring on the depression? No. Wall Street only dramatized a condition which lay deeper . . .
>
> Let us go back to that spring morning on State Street in 1913. By that time, the American frontier had closed, the rates of population and production growth were leveling off. All the world had been pretty well divided up by the Great Powers, with colonial development slackening. Backward nations were beginning to build their own factories. In 1914 a depression came. It might have been a serious depression but we pulled out of it on war orders and spending for armaments, until every able-bodied man was in the army or employed. After the war, we fell into another depression. We pulled out of that on deferred construction, foreign loans, installment credit and the giant motorcar and highway investment. Other nations were not so fortunate. They remained mostly in a trough of permanent depression. . . .
>
> Dr. Alvin H. Hansen of Harvard, in summarizing the period, says that there can be little question that the boom in investment during the twenties, followed by saturation in investment outlets and the decline in the output of fixed capital goods, was the central core of the great world depression, and determined mainly its intensity and duration. Observe that the depression was not due to government interference. Businessmen, keeping cool with Coolidge and hot with Hoover, had a relatively free hand. The unions were quiet. The socialists had declined to a political pinpoint. The radicals were reading H. L. Mencken or writing advertising copy . . . .
>
> Down, down, down. Unemployment grew from an estimated 2 million in 1929 to 15 million in 1933, nearly a third of the whole labor force of the country. National income dropped from 80 billion dollars to 40 billions; the value of manufactured products from 70 billions to 31 billions. In 1932, corporations as a group were 6 billions in the red, and 68,000 industrial concerns dropped into limbo. At one time, the construction industry was operating at less than 20 per cent of its 1929 volume, and for five years it made no profits at all. By 1934, 45,000 miles of railway lines were in receivership. The sale of durable goods fell to a third of its 1929 level, and foreign trade was off 65 per cent. The cash income of all farmers was 13 billions in 1920, 11 billions in 1929, 5 billions in 1932. Wheat was selling at 32 cents a bushel, cotton at 6 cents a pound, beef at $3.20 a hundredweight. Wheat on the Liverpool market fetched the lowest price since the reign of Charles II. . . .
>
> The New Deal went into action on all fronts—financial, agricultural, industrial, and just plain human. . . .
>
> The federal government was receiver for a bankrupt economy. History will record it so. The economy was bankrupt not only in a flow of goods inadequate to keep millions of its people above the line of destitution, bankrupt in the utter collapse of business leadership, but bankrupt technically. The whole banking system was insolvent in 1933; liabilities exceeded assets at current valuations. Whatever the economic structure was which had brought a great nation to this pass, it was not good enough. Its moral beauties, if it had moral beauties, could not longer offset the tragic fact of people beaten to their knees, workless and starving in a land of material plenty. A structure which better fitted the necessities of survival in the power age had to be found, and the New Deal was the first attempt to find it. . . . (pp. 37–43).

In section 2, Chase attempts to marshal evidence bearing out his thesis that technological, population, and geographical trends lead to a decline in investment opportunities, with the inevitable consequences of unemployment, war, monopoly, contracting, and expanding governmental functions.

In the last part of the first volume and throughout "Goals for America" Chase attempts to outline a "budget" of our needs and resources involving the "Big Five"—food, clothing, shelter, health, and education. He holds that we cannot move back to the poverty and unemployment of the thirties, nor even stand still. We can and must push forward, and for success there will be required a tremendous *joint* effort on the part of government and business.

Even if the reader does not agree with this entirely, these books and those to follow will give him new insight into the shape of things ahead.

THE SOLDIERWELDER A KEY FIGURE IN WAR EFFORT

(Trainee watches an instructor in the correct and safe manner of employing a torch, at the Quartermaster Replacement Training Center, Camp Lee, Va., commanded by Brigadier General Guy I. Rowe, with Col. James H. Johnson as director of motor training. The soldierwelder receives his training at the blacksmith and welding school which is in charge of Captain J. L. Bauer. The trainees are instructed in blacksmithing, oxyacetylene and electric-arc welding. When these welders are graduated they can be turned over to Ordnance. The welder is an essential soldier in the work of keeping the great fleets of trucks ever-moving to the battlefront. Repairs must be durable as a breakdown in the midst of a convoy may prove disastrous. The main building of the school is equipped with fifteen gasoline-driven dc welding generators and four elecrically driven dc welding generators.)

BRIEFING THE RECORD

Abstracts and Comments Based on Current Periodicals and Events

MATERIAL for these pages is assembled from numerous sources and aims to cover a broad range of subject matter. While few quotation marks are used, passages that are directly quoted are obvious from the context and credit to original sources is given.

Aircraft Plywood

AERONAUTICAL ENGINEERING REVIEW

MANY of the rapid and extensive developments in plywood that have resulted from the urgency of the material-substitution and aircraft programs have been brought to the attention of A.S.M.E. members by papers presented by the Wood Industries Division. Early in 1943 Thomas D. Perry, who has been one of the most active members of the division for many years, presented a report on "Progress in Aircraft Plywood, 1941–1942," at the Aircraft Production Session, Institute of the Aeronautical Sciences, Jan. 25–29, 1943, published in *Aeronautical Engineering Review*, February, 1943.

The place accorded plywood in the aircraft program, said Mr. Perry, has been markedly enlarged in the last two years. Military and naval training planes of various types are being manufactured by factories that formerly made Cub and small private planes. Wing coverings and control surfaces in these types are plywood on plywood and wood framework. Fuselages have substantial portions of plywood. In the glider program, glider trainers are frequently engineless private planes; cargo gliders with their wide wingspread are predominantly plywood, mostly curved and fitted from flat plywood sheets; troop-carrying gliders follow the same structural characteristics. The cargo planes, with engines, have major portions of plywood, utilizing metals for the more heavily stressed members. In the combat field, fighters, scouts, bombers, and torpedo planes reveal a growing number of plywood members such as doors, seats, floors, flaps, rudders, control surfaces, and the like.

Molded plywood by the flexible-bag process is finding wide use in compound curved and monocoque shapes where flat plywood is wholly inadequate. More than 25 factories now have such molding equipment. The demand for flat plywood is taxing the capacity of nearly 100 factories. High-density and impregnated plywood are both finding growing recognition where hardness and strength are predominant. The use of radio-frequency power for converting resin adhesives is expanding rapidly.

A candid appraisal of the situation indicates the definite adoption of plywood where strength-weight factors and workability are dominant, of metals where extreme strength is needed, of fabrics and of molded plastics where these materials may be found adequate.

Mr. Perry reviewed improvements that have been made in resin adhesives and the importance of the pressure requirements when this type of adhesive is used. The conventional method of applying heat for the cure of resin adhesive bonds, he said, has been that of steam, usually circulated in the flat or slightly formed platens of a hot press, as shown in Fig. 1 (I). In this case the heat penetrates the plywood assembly from the upper and lower surfaces. As a consequence the exterior of the plywood is considerably hotter than the interior. When it is realized that the heat is used wholly to cure or convert the resin, it becomes apparent that this method is particularly adaptable only to relatively thin plywood, perhaps up to approximately 1 in. in thickness. Thicker assemblies will heat slowly and consequent difficulties may be encountered. However, since steam of 100 lb pressure is almost always available in industrial plants, this method of heating will find wide acceptance and in most instances will give satisfactory results.

A more recent method of heating wood assemblies is with radio-frequency power, often called high frequency, and quite similar in general principles to the diathermy apparatus employed by physicians. With this equipment, one type of which is shown in Fig. 1(II), the wood or veneer assemblies are placed between insulated (*G*) electrodes, *D* and *D'*, and these electrodes are connected to the two terminals *E* and *F* of a short-wave high-frequency generator. This generator is of the order of the equipment used in a radio broadcasting station. The advantage of this method in the cure of resin adhesives is the fact that all portions of the wood assembly within the electrostatic fields *H* are raised to the same temperature almost simultaneously, and the heat uniformly permeates the entire assembly. The difficulties of the surface application of steam heat and its slow penetration toward the interior are eliminated. The rate of heat increase throughout the assembly will depend on its bulk, i.e., when the bulk is doubled, the degrees of temperature increase per minute will be approximately cut in half. The rate of heat increase can, of course, be maintained by doubling the power input. This process is therefore especially adapted to thick assemblies that are difficult to heat in any other way. How far it may be adapted to thin plywood with economy in comparison with steam-heated platens has not yet been determined.

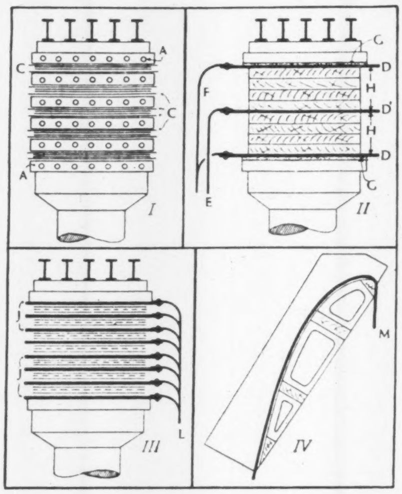


FIG. 1 METHODS OF HEAT APPLICATIONS

I Conventional hot platen press.
A = Steam-heated platens.
C = Aluminum cauls.
II Wood assemblies, heated between high-frequency electrodes.
D, *D'* = Electrodes, establishing electrostatic field, *H*.
E, *F* = Wire connections from transformer to fields, *H*.
G = Insulating pads.
H = High-frequency fields, containing wood assemblies.
III Conventional plywood press, without hot platens.
J = Electrical resistance plates, used as cauls.
L = Standard electrical connections.
IV Pressure jig for assembly work.
M = Strip heater, to cure resin adhesive between skin covering and rib.

Still a third method of applying heat in the cure of resin adhesives is that of electric-resistance plates, with heating units installed therein, similar to those in electric flatirons. This heat can be obtained from ordinary electric-current sources and is thus easily available. One method of applying this process to flat plywood is shown in Fig. 1(III), where the resistance plates are used in plywood manufacture instead of the usual aluminum cauls. Such resistance plates can be used in many types of presses and clamps where the distance of required heat penetration is not so great as to char the wood.

These resistance plates are also made in the form of strip heaters and can be employed on moderately curved surfaces, as shown in Fig. 1(IV). In this instance the cure of the resin is for an assembly operation, a skin covering of plywood to a fabricated rib and spar. This heat application permits the use of a heat-reactive resin of the phenolic type, although it can also be used to accelerate the cure of a urea adhesive of the cold-setting type. Phenolics are characterized by a better durability than the ureas and are more desirable to use where conditions permit.

Mr. Perry also touched on the interesting subject of impregnated veneers. There have been distinct advances in this field and the terms "Impreg" (impregnated wood) and "Compreg" (compressed and impregnated wood) have gained recognition, along with the more general term "high-density plywood." Careful study has revealed that the impregnating resins, usually of the phenol-formaldehyde type, must be of small molecular size, i.e., taken off in an early stage of the condensation process so as to penetrate thoroughly and permeate the minute openings in the spongy cell walls or enclosures of the wood cells. Either water or alcohol solutions of the phenolic resins can be used for impregnating applications, and there are proponents of both types. The adhesive resins, products of a more advanced stage of condensation, are not generally suitable for high ratios of impregnation; hence in most cases it is desirable to impregnate the sheets of veneer with one type and to cause the sheets to adhere to each other with a different type of resin. The resin-impregnation developments thus far have been largely limited to sheets of veneer not more than $^{1}/_{8}$ in. thick.

There are several objectives to be gained in the impregnation of veneer and plywood, namely, that of densification of any species to any desired extent, of strength increment, of compressibility, and of dimensional stability under conditions of severe exposure.

Impregnation is secured by immersing the sheets of veneer in solutions of the impregnating resins. If this soaking is done at normal atmospheric pressure, the veneer should be steamed to maximum moisture content and soaked for a matter of hours, sometimes as long as a day. Often a subsequent period for the diffusion of the impregnate deeper into the wood is found necessary before drying out the impregnating solvent. If this soaking can be done under a vacuum-pressure or a pressure process, the time can be shortened to several cycles of approximately 20 min each, a cycle being 10 min under 50 lb pressure and 10 min at atmospheric pressure. After impregnation by any of the foregoing methods, the saturated veneers should be dried to avoid blisters from the heat of resin cure. Tests appear to indicate that a resin pickup of 25 to 30 per cent gives the optimum results. Pickup can be defined as the percentage of increased weight in the dry, cured, and impregnated block over the original dry weight of the veneer.

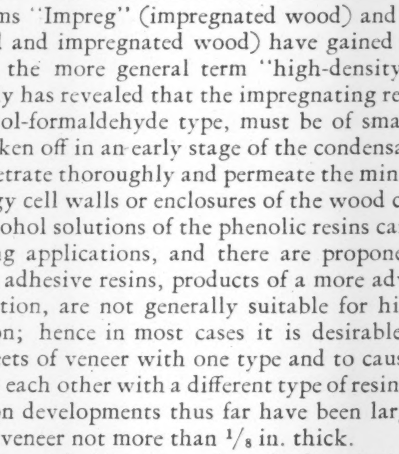


FIG. 2 COMBINATION ASSEMBLIES OF LOW AND HIGH DENSITY. (*A*) OUTER LAYERS OF HIGH-DENSITY VENEER; (*B*) INNER LAYERS OF HIGH-DENSITY VENEER; (*C*) ALL LAYERS OF HIGH DENSITY, WITH INTERLOCKING SURFACE

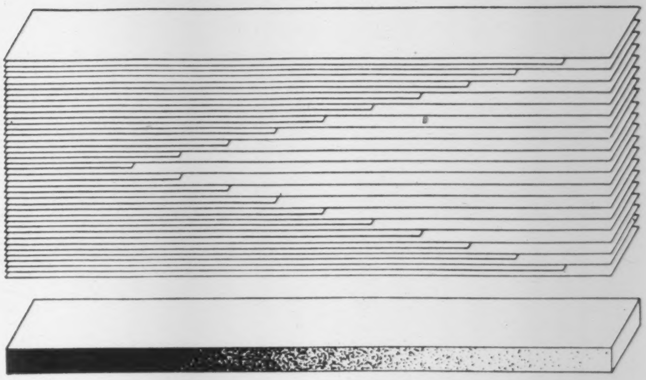


FIG. 3 VARIABLE DENSITY, BEFORE AND AFTER PRESSING. UPPER: ALTERNATE PROGRESSIVE SHORTENING OF LAYERS. LOWER: AFTER PRESSING TO UNIFORM THICKNESS

The resin in such impregnated veneer can be cured without pressure, or with a normal pressure of 150 to 250 lb, or made into compressed products at pressures of from 500 to 3000 lb. When such veneers are to be assembled into plywood, it is advisable, although not always necessary, to use a supplementary adhesive to bind the layers together. Both the impregnating and adhesive resins can be cured in a single heat exposure.

The arrangement of impregnated and unimpregnated veneer layers may be varied both as to grain direction and as to sequence. The greatest stiffness will be secured by placing the layers with parallel grain; in fact, the alternating grain directions of normal plywood have not been found to be particularly advantageous in the more highly compressed products.

Since the impregnation adds distinct weight to the veneers, it is possible to secure surface density, without too much sacrifice of lightness, by assembling impregnated outer veneers and normal untreated inner veneers, as shown in Fig. 2 *B*. These high-density outer layers will take the place of the usual sealers, undercoaters, and the like. Usually, the total finished weight with densified surface-veneer foundation will be less than normal undensified plywood finished by the conventional procedure. Another assembly combination, where it is desirable to preserve a gluable surface and still obtain the qualities of the impregnated and compressed veneers, is shown in Fig. 8 *A*, where the outer layers are normal untreated veneers and the inner layers are fully impregnated. While such normal surface veneers may be somewhat compressed at first, they will tend to return to normal conditions by slight wetting after pressure release. They will present surfaces on which glue joints can readily be made. Still a third type of assembly, in which all layers are impregnated and compressed, is shown in Fig. 2 *C*. Here one or both sides of the high-density sheet may be pressed during the heat-pressure cycle, against a plate having a pattern of slight depressions. These depressions will produce small humps or knobs on the resulting high-density plywood. When used as an anchor plate against a spruce spar, these knobs can be forced into the softer spruce by the pull of the bolts, and a superior mechanical lock will result. Such mechanical locking surfaces can be as large as necessary to transmit the required loading.

If a variable-density piece is desired, the successive layers of veneer can be progressively shortened, as shown in Fig. 3. When such an assembly is pressed to a uniform thickness, the density will be greatest at the thicker original section where the impregnated wood is most highly compressed, as can be noted in the lower part of the illustrations. Such higher-density sections can be located as desired. This construction is under serious consideration for large propellers and is said to be extensively used in England.

Working Aluminum

ALUMINUM COMPANY OF AMERICA

TWO useful booklets, published by the Aluminum Company of America, will be welcomed by anyone engaged in welding or machining this material: "Welding and Brazing Alcoa Aluminum" and "Machining Alcoa Aluminum and its Alloys."

On the subject of welding, the booklet covers gas welding, arc welding, and electric resistance. On brazing, the points covered are preparation for brazing, furnace brazing, torch brazing, and dip brazing, the brazing of castings, and the cleaning of joints after brazing.

The booklet on machinery contains two parts, general machinery practice and automatic-screw-machine practice. Eight tables give data on the composition of the commercial aluminum alloys; cuts, speeds, and feeds; mechanical finishing; approximate feeds for standard tools for machining Alcoa 11S-T3 alloy; physical and mechanical properties of alloys 17S-T, 24S-T, and 11S-T3; comparative weights of standard screw-machine stock; and tolerances.

Dustless Treatment of Coal

BATTELLE MEMORIAL INSTITUTE

TO insure that producers of bituminous coal may be able to treat coal properly to reduce the dust in handling, Bituminous Coal Research, Inc., has under way an extensive program of research into the materials now on the market or under development for this purpose. Although the studies are not complete, a progress report, "The Dustless Treatment of Coals With Calcium Chloride and Other Materials," by Ralph A. Sherman and George W. Land, has been issued by the Battelle Memorial Institute on behalf of Bituminous Coal Research, Inc., in co-operation with The Calcium Chloride Association.

The information presented in the report is principally concerned with calcium chloride as applied to four types of coal. The data that have been obtained at present on the use of calcium chloride and of a paper-mill liquor, Clarion extract, lead to the following conclusions which must be considered tentative because further work is in progress: (The dustiness determinations were made after storage in an atmosphere of 55 per cent relative humidity.)

Based on tests one week after treatment, calcium chloride satisfactorily reduces the dustiness of domestic stoker coals from seams having inherent or bed moisture contents of 8 per cent or less.

Coals of high inherent moisture content, of the order of 18 per cent, are not effectively treated with calcium chloride because of the rapid absorption of the treating material into the coal.

The dustiness of coals treated with calcium chloride increases with time of storage because of absorption of the treating material into the pores of the coal but even after three months of indoor storage, the dustiness of coals having inherent moisture contents of 8 per cent or less is much lower than for the untreated coals.

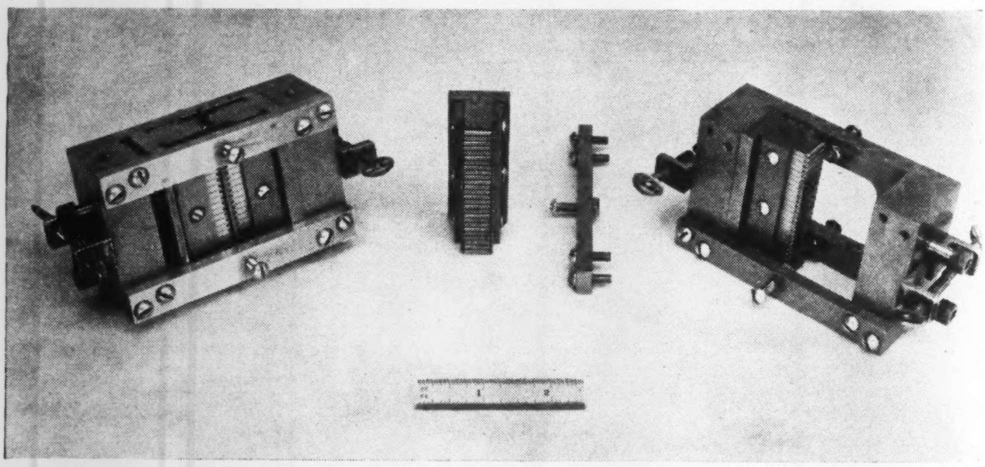
A high relative humidity should be maintained in the coal-bin to decrease the dustiness of coal treated with a hygroscopic material such as calcium chloride. To do this the bin should be sealed from the basement to prevent air circulation and to keep the bin cool. Occasional sprinkling of the surface of the coal with water will also be helpful.

The rates of application required for effective treatment differ for various coals, but are of the order of 7 to 10 lb of calcium chloride per ton of coal for coals having inherent moisture contents of 8 per cent or less.

The experiments have not shown a conclusive superiority of either method of application of calcium chloride, dry or in solution, but if dry flake calcium chloride is applied to dry coal, the addition of water at the time of treatment is advised to obtain rapid uniform distribution of the calcium chloride over the coal.

The paper-mill liquor, Clarion extract, was not effective by itself in reducing the dustiness of coal, but the application at the rate of three gallons per ton of coal of a solution of two parts of the extract with one part of water plus $1^{1}/_{2}$ lb of calcium chloride per gallon of solution was very effective in reducing the dustiness of one coal of 3.2 per cent inherent moisture, Elkhorn seam, and this effectiveness was well maintained after one month's storage.

Although iron or steel wet with water will corrode, it will be expected to corrode more when exposed to calcium chloride



JIG TO DETERMINE COMPRESSION YIELD STRENGTH IN AIRCRAFT DESIGN

(A new jig for the determination of compression yield strength in aircraft design has been developed, making it possible to test a single thickness of sheet metal in compression supporting the sheet in the jig, as shown, with a multiplicity of small rollers. The extensometers are attached to the edges of the sheet. The testing of the material in single-sheet form requires a smaller load and simplifies the technique of testing to a large extent. The jig, simple and inexpensive, reduces the apparatus to its lowest terms.)

or other salt solutions. Hence care must be exercised in washing and painting metal equipment with which these solutions come in contact. Experience shows that with reasonable care no serious difficulty will be encountered.

Care must be taken that the treating solution is not made with acid mine water or that, if acid water must be used, its acidity is neutralized. Contrary to common belief, calcium-chloride solutions, as prepared for coal treatment, are not acid if the water used in their preparation is not acid.

Preliminary experiments on the corrosion of screws of residential stokers show that if the stoker is so operated as to produce excessive temperatures, of the order of 300 F or higher, in the coal feed tube, the calcium chloride on coal treated with calcium chloride may be decomposed with the liberation of hydrochloric acid which can attack steel when the acid meets water with which it may combine. The adjustments on the stoker to prevent these high temperatures in the coal feed tube are those that result in the best performance of the stoker.

The low freezing points of solutions of calcium chloride make it a desirable material for prevention of freezing of wet-cleaned coal. The difficulties of unloading cars of frozen coal at destination can be avoided when adequate amounts are properly applied.

The amount of calcium chloride required will vary with the surface moisture of the coal and the temperature to which it is desired to protect against freezing. For protection of coal containing 2 per cent surface moisture to 20 F, 170 lb are required per 50-ton car; for a coal of 10 per cent surface moisture to 0 F, 1650 lb are necessary.

Application of one fourth of the total amount on the bottom and sides of the car and the remainder uniformly through the car in the upper half of the car is suggested to avoid loss of the calcium chloride through drainage.

Specific Heats of Gases

CORNELL UNIVERSITY ENGINEERING EXPERIMENT STATION

THE increasing use of high temperatures and pressures in industrial processes has made necessary accurate and reliable information as to the specific heats of the working mediums used. In a bulletin entitled "The Specific Heats of Certain Gases Over Wide Ranges of Pressures and Temperatures," the authors, Frank O. Ellenwood, Nicholas Kulik, and Norman R. Gay, present the results of a study on air, CO, CO_2, CH_4, C_2H_4, H_2, N_2, and O_2, which are of primary importance to the engineer.

The bulletin gives the general equations which determine the effect of pressure on the specific heats of the gases, within the ranges of temperature and pressure encountered most frequently in engineering practice. For the gases considered in this paper, the variations of specific heats with temperature and pressure are also shown graphically.

The results are based on the two following fundamental assumptions:

(1) That recent experimental spectroscopic data give values of the specific heat of a rarefied gas at constant pressure, which are reliable within the range of the temperatures considered.

(2) That the Beattie and Bridgeman equation of state may be applied within the limits of accuracy required to give the specific heats at the other pressures covered by the calculations and curves.

The method applies to all gases, if the proper constants which enter into the equations are known.

The results show that the common practice of ignoring the effect of pressure on the constant-pressure specific heat may involve considerable error. The magnitude of this error, however, depends upon the pressure, temperature, and gas under consideration, as shown by the curves.

An inspection of the curves of specific heat against temperature shows that all the curves are similar and that the greatest dependence of c_p on pressure is near the critical point. This result is as would be expected, because the value of c_p becomes infinite at the critical point. As the temperature increases, however, the dependence upon pressure decreases and the value of c_p approaches the value of c_p at zero pressure as a limit.

The magnitude of c_v, the specific heat of a gas at constant volume, is very dependent upon temperature but is only slightly affected by pressure, unless the temperature is low.

Tanker S.S. "Schenectady"

AMERICAN BUREAU OF SHIPPING

FOLLOWING is a report of the findings of the special subcommittee appointed by the American Bureau of Shipping to investigate the structural failure of the tanker S.S. *Schenectady*. Members of the Committee were A. G. Bissell, senior welding engineer, Bureau of Ships, Navy Department, Washington, D. C.; Erland D. Debes, welding engineer, Bethlehem Steel Co., Shipbuilding Division, Quincy, Mass.; LaMotte Grover, structural welding engineer, Air Reduction Sales Co., New York, N. Y.; A. A. Norton, hull superintendent, Sun Shipbuilding & Dry Dock Co., Chester, Pa; Harry W. Pierce, welding engineer, New York Shipbuilding Corp., Camden, N. J.; Prof. S. H. Graf, consulting materials engineer and metallurgist, professor of mechanical engineering, Oregon State College, Corvallis, Oregon (consultant on steel investigation); including ex-officio members J. Lewis Luckenbach, president, D. Arnott, vice-president, chief surveyor, and J. L. Wilson, assistant chief surveyor, American Bureau of Shipping.

DESCRIPTION OF CASUALTY

The S.S. *Schenectady* (503 ft × 68 ft × 39 ft 3 in.) is an all-welded tanker exactly similar in design to ships built and building by the Sun Shipbuilding and Dry Dock Company, Chester, Pa., of which no fewer than 23 have been placed in operation in the past year and which, to the best of our knowledge and belief, have shown no structural defects in service.

The *Schenectady* was the first tanker built at the new shipyard of the Kaiser Company at Swan Island, Portland, Ore.; had been launched Oct. 24, 1942, and had satisfactorily completed her sea trials. She was lying afloat at the fitting-out dock of the Swan Island Yard when, on Saturday evening, Jan. 16, 1943, she broke in two with a loud report, fracturing suddenly across the deck at a point just abaft the afterend of the bridge about amidships, the fracture extending down both sides to the bottom shell plating which remained intact. All deck, side, and bottom longitudinal frames fractured as did also the plating of the corrugated longitudinal bulkheads and the centerline deck and bottom girders thus constituting a complete structural failure except for the flat portion of the bottom shell plating. In no case did the fractures occur in the transverse welds.

The vessel jackknifed so that the bottom shell plating knuckled transversely and showed above water while the ends of the forward and after sections settled in the silt so that there was a gap of about 10 feet at the deck. There was no leakage of water into the two parts of the tank opened by the fracture and from the character of the fracture the tearing of the side shell appeared to have been more gradual and progressive than the sudden fracturing of the deck from gunwale to gunwale.

The forepeak tank, the forward deep tanks, and the afterpeak tank were full of water as ballasted for the trial trip and there was in addition about 3100 barrels of fuel oil in the cross bunkers immediately forward of the machinery space. The resultant bending moment in hogging in still water was about one half of the maximum design bending moment.

The hourly temperature for Saturday, Jan. 16, 1943, reported by the U. S. Weather Bureau for Portland, Ore., shows a high of 38 F at 2:30 in the afternoon, and 23 F at 11:00 p.m. at the time of the failure. The river-water temperature was about 40 F. This drop in air temperature of 15 F over a period of $8^1/_2$ hours, while not extreme as to suddenness, did introduce a factor in respect of the increased brittleness of steel at temperatures below freezing.

It was alleged that during the launching of the vessel trouble was experienced with the after launching poppet which resulted in slight damage to the rudder and its pintle but there was no evidence that such trouble contributed to the failure.

It was alleged that during the trial trip one of the anchor chain cables broke as the anchors were dropped to check the vessel's headway, resulting in a definite shock, but this could not have been great enough in magnitude to be of any consequence.

It was alleged that the action of the Williamette River had washed a bank of silt under the midship portion of the vessel and that a subsequent drop of river level had in effect caused a stranding. While there was a recorded drop of about 15 in. in water level for the $3^1/_2$-hour period immediately preceding the failure, there was no evidence of such a silt formation. Subsequent examination of the vessel in dry dock, by the committee, disclosed no indication of grounding damage.

It was also alleged that several people felt a slight seismic disturbance (an earth tremor) at the time of the failure. This was further colored by the fact that the water-level indicator located at the yard showed a vertical oscillation of approximately 12 in. at the moment of failure and it is claimed that extreme oscillations of these level indicators always accompany earthquake disturbances. After a thorough investigation it was concluded that the alleged shock had little bearing on the cause of this failure.

FACTORS CONTRIBUTING TO FAILURE

After a thorough study of all factors surrounding the failure, including structural design, methods of construction and a complete physical, chemical, and microscopic exploration of the material and the welding in way of the fracture, the committee found the following factors relevant and contributory to the failure.

(*a*) There was a tendency on the part of the shipyard personnel to depart from recognized fundamentals of good welded construction for the laudable purpose of speeding up construction to the utmost possible extent to meet the needs of the present emergency.

(*b*) There was not a sufficient number of trained experienced welders and shipfitters available for the job at the rate of production maintained and an inadequate number of skilled welding supervisors with the necessary knowledge of the basic elements of good welding practice to exercise proper control over the welders.

(*c*) There was neglect on the part of the personnel to realize the importance of adhering rigidly to established welding procedures and welding sequences necessary to reduce shrinkage stresses to a safe minimum.

(*d*) There was evidence in the sister vessels under construction of poor fitting of large subassemblies which necessitated considerable forcing into position by the excessive use of jacks, turnbuckles, etc. In other cases open joints required the use of an excessive amount of welding to finish the joint resulting in excessive shrinkage.

(*e*) There was a lack of uniformity in the quality of the steel used in the hull structure. For example, as compared with other plates investigated, the particular sheer-strake plate on the starboard side where the fracture apparently started had a very low proportional limit (10,000 psi) as determined by extensometer readings (stress-strain curve); also the Charpy test impact values for this plate were low, even at room temperatures, and brittle at 20 F; the values from the notch bend tests also showed considerable brittleness. It should be recognized that the Charpy and notch bend tests are not included in the ordinary commercial tests by which the quality of structural steel is determined.

(*f*) A serious accumulation of shrinkage stresses occurred in the automatic machine welding of the deck assembly joints especially in the longitudinal joint at the gunwale attaching the sheer strake to the stringer plate. This particular welded joint was also found defective in way of the location where the failure started as evidenced not only by a longitudinal crack but also by what appeared to be minute transverse cracks in the weld.

(*g*) The hogging moment resulting from the distribution of ballast, fuel, etc., in the end tanks produced a tensile stress on the upper flange of the hull girder of approximately $4^1/_2$ tons psi, which is comparatively moderate and certainly not sufficient in itself to cause any failure in the hull structure.

(*h*) While there is no question with regard to the sufficiency of the vessel's structure, there being no departure from recognized and proved design standards, the abrupt termination of the bridge-end fashion plates at the top of the sheer strake did constitute a serious point of stress concentration especially in a welded structure.

SUMMARY

In the opinion of the committee the failure of the hull structure of the tanker *Schenectady* was due to a combination of unfavorable circumstances. The principal cause was an accumulation of an abnormal amount of internal stress locked into the structure by the processes used in construction together with an acute concentration of stress caused by defective welding at the starboard gunwale in way of the abrupt ending of the bridge fashion plate, augmented by the hogging stress due to the ballasted condition; this accumulation and concentration of stress caused a tensile failure at the starboard sheer strake which was formed of steel of substandard quality, all of which was aggravated to some degree by the drop in atmospheric temperature.

CONCLUSION

The procedure immediately recommended and carried out whereby the defective welding previously referred to was removed from the S.S. *Schenectady* and sister vessels and these joints properly rewelded has proved a satisfactory corrective measure as demonstrated by the application of severe bending tests (hogging and sagging). It is the opinion of the committee that the high stresses responsible for the fractures that have recently occurred in welded vessels were due primarily to the failure to adhere rigidly to the procedure necessary to keep shrinkage stresses within the margin of strength allowed in the design. Steps have been taken with the full co-operation of all yards concerned to insure adherence to proper established procedure and the managements of the yards are fully alive to their responsibilities in the matter. The committee feels that closer control of welding procedure in which the builders have already been instructed will prevent a recurrence of such major failures. It is also the opinion of the committee that the probability of fractures resulting from residual stresses in welded construction will decrease with the length of service.

ANOTHER view of the reasons for the failure of the S.S. *Schenectady* will be found in a letter published elsewhere in this issue, page 372—EDITOR.

COMMENTS ON PAPERS

Including Letters From Readers on Miscellaneous Subjects

Surface Finish of Journals

Comment by J. T. Burwell, Jr.[1]

The authors are to be commended for their contribution to the subject of the dependence of bearing operating characteristics on the surface finish of the rubbing surfaces. This is becoming an important subject, and much needs to be done in the way of collecting carefully determined data covering a wide range of surface finishes, bearing materials, and operating conditions. The present paper[2] fills in a gap in a very important section of this field. More work of a similar nature is greatly to be desired.

Some data of a similar nature have been obtained and published by the writer and others.[3] In that investigation babbitt bearings were used instead of copper-lead; a somewhat wider range of surface roughness was covered but there was less variety of types of finish and there was very little comparison of different types having the same root-mean-square roughness. Also the criterion of performance was taken as the minimum of the ordinary friction-coefficient curve or the point where the hydrodynamic oil film begins to fail. Within these limits, it was concluded that the smoother surfaces had a lower value of $(D/C)^2(\mu N/P)$ at the minimum which generally means, for a given speed and oil, a higher load capacity. It is interesting that the present work, though investigating a different range of the variables and using a different test procedure, substantiates this conclusion although, as the authors point out, care should be taken in determining just what the roughness of the surface really is.

Some extension of the work referred to[3] has been carried out using copper-lead bearings in the same test procedure and against many of the same shaft surfaces described previously. The results in general agree with those of the present authors. One particular surface gave somewhat unexpected results, and it might be of interest to mention it. The test shaft was ground undersize and then built up to its original diameter by spraying with steel metal. The surface was finished by grinding, using a wheel which, on solid stock of comparable hardness, produced a roughness of 10 to 15 μ in. rms. Actually the metal-sprayed surface ground with this wheel had a roughness of 60 μ in. This was due to numerous pits which were visible to the naked eye and presumably were sections of interstices throughout the sprayed-metal structure. This surface proved to be anomalous in two ways when run against either babbitt or copper lead. Even in the hydrodynamic region of the friction-coefficient curve, it ran hotter than any other shaft for the same speed, load, oil, and D/C ratio. The friction curve lay considerably above those for all the other surfaces, indicating greater friction for a given value of viscosity, speed, and load. Its value of $(D/C)^2(\mu N/P)$ at the minimum of the friction curve, which is a general measure of the load capacity, lay between that for a 15-μ in. surface and that for a 60-μ in. surface. In other words, its load capacity was greater than that of a ground surface of 60 μ in., presumably because that portion of the surface between the pits which actually bore the load was flat and had a roughness of only about 15 μ in., but its load capacity was not as great as a solid 15-μ in. surface, presumably because of the presence of the pits. Apparently the presence of these pits in the otherwise smooth surface was detrimental. The reasons for this, as well as for the fact that it ran hotter than other shafts, are as yet unexplained. A complete account of this work will be published shortly.

The observation of the authors that loose-abrasive lapping gave somewhat poorer than average results is interesting. Schlesinger[4] has studied the lapped surface of a piston pin and concluded, in this particular case, that the scratches could account for a loss of as much as one third of the nominal bearing area. This was concluded both from direct photographs of the surface and also calculated from a profile recording. Possibly this could explain the author's observation.

The fact that there is a correlation between the initial seizure load and the product of the two roughnesses measured in the parallel and transverse directions is interesting particularly when the variety of finishes used is considered. For the surfaces tried, as Table 5 of the paper shows, the two roughness readings are not very different. It would be interesting to determine whether the same correlation holds if surfaces having a more extreme directional character are tried. Consider, for instance, a turned surface prepared by a carefully sharpened tool. If the profilometer stylus stays in one groove the roughness reading may be quite small even though the transverse reading is large, and it is doubtful whether the seizure load would be very high. In this case it is possible that the product of the roughness would predict a higher seizure load than is actually found. It is possible that the product of the two roughnesses is a first approximation to the true expression and holds if the two are not too dissimilar. It seems doubtful whether the relationship between load capacity and surface contour can be described in terms of one parameter for all the possible types of surfaces.

Comment by C. K. Gravley[5]

The comparison made of journal-bearing performance versus the product of roughness measurements, made axially and circumferentially on the surfaces tested, may be subject to some error because of possible inaccuracies of circumferential roughness measurements.

Roughness-measuring instruments are not ordinarily equipped with fixtures for measuring circumferential roughness and, if a meter reading only is obtained, there are apt to be two possible sources of error:

1 The circumferential roughness that is obtained from most finishing operations is made up of irregularities with much longer waves than those which are normally measured when a trace is made axially along such parts. This requires that the tracer be moved at a greater velocity over the specimen since these instruments are limited in the frequencies which they will measure.

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[1] Lieutenant (j.g.) U.S.N.R., Office of the Co-Ordinator of Research and Development, Navy Department, Washington, D. C.

[2] "Surface Finish of Journals, as Affecting Friction, Wearing-In, and Seizure of Bearings," by R. W. Dayton, H. R. Nelson, and L. H. Milligan, Mechanical Engineering, October, 1942, pp. 718–726.

[3] "Effects of Surface Finish," by J. T. Burwell, J. Kaye, D. W. van Nymegen, and D. A. Morgan, *Journal of Applied Mechanics*, Trans. A.S.M.E., vol. 63, 1941, pp. A-49 to A-58.

[4] "Surface Finish, Report of the Research Department of the Institution of Production Engineers," by Dr. George Schlesinger, Director, London, Eng., January, 1942, p. 83 ff.

[5] Chief Engineer, The Brush Development Company, Cleveland, Ohio.

2 A possible source of error is caused by the difference in the radius of the positioning shoe or skids, and tracer point. If the tracer is made to trace a curved surface, the tracer point will be actuated by curvature of the part, as well as by the roughness on the part. If the velocity that is imparted to the point by the curvature of the part is high enough, these motions, as well as the roughness, will be read by the meter.

The writer wishes to point out that both of these errors can be accounted for by the recording type of instrument, because the measure of the scratch frequency is obtained directly from the chart and the measure of curvature is shown by a very low-frequency wave in the roughness record.

COMMENT BY E. L. HEMINGWAY[6]

In a recent article[7] the writer presented some ideas on the necessity of minute oil grooves or pockets, under conditions of incipient galling. In it, the following sentence appeared: "A decision as to the number and distribution of pockets would seem to depend upon the extent of area that one of them could momentarily lubricate, or at least contaminate sufficiently that galling could not occur."

It is the writer's belief that the authors have the answer to this problem for the particular conditions obtaining in their procedure. It is also believed that just this sort of investigation will lead to much improved bearing operation.

This work proves the thesis that a score-free bearing surface must be a compromise between the maximum of load-carrying area, and sufficiently minute distribution of the lubricant through scratches or pockets. Under the conditions of their procedure, it appears that the area which can be lubricated by the oil contained in one scratch is extremely limited. Sandpapered surfaces are more efficient than ring-lapped, because they contain a uniform and closely spaced alternation of very minute load-carrying ridges and of oil-retaining valleys, while the lapped surface has relatively large smooth areas between scratches or pits.

The results secured by ring-lapping followed by sandpapering seem extremely important. As the geometrical shape of a bearing surface becomes more perfect, and the load is thus more uniformly distributed over a larger area, its lubrication under a given high loading tends to become less of a boundary and more of a full fluid nature. The exact distribution of oil through scratches would then seem to be less important or a still higher load could be carried with the same scratch condition.

Needs has reported that an oil film between two optical flats becomes incompressible at a thickness of 0.00003 in. Claypoole finds that the maximum efficiency is present in oil films of much less dimension. If it were possible to produce a bearing surface of still greater geometrical accuracy and alignment than the dimension of such an oil film, it appears that no scratches for oil would be necessary or advisable in any case because that oil film would be incompressible and impenetrable. The loading on such a bearing would not be limited by the capacity of the oil film, only by its mechanical strength.

Further improvement in bearing surface will be accomplished by attention to removal of surface waviness, and by such determination of the most efficient surface oil-groove patterns as the authors have made. We cannot produce accuracy of the degree mentioned, and, under conditions of boundary lubrication or incipient scoring, minute scratches appear to be necessary. However, attention should be called to the fact that the most efficient surfaces were found to be those of lowest profilometer reading. The scratches must be exceedingly minute.

The authors' rating of surface according to the product of profilometer readings in Table 5 of the paper seems questionable. The profilometer reading depends upon two factors, i.e., the height of the scratches and the number of them passed over each second by the stylus. The instrument does not give its true reading until 20 scratches per sec are traversed. Thus the stylus must be moved more rapidly lengthwise of the scratches than across them to find their average height, but that height is the same in either direction. However, if a movement of a standard speed is used, such a procedure might give useful information.

COMMENT BY C. R. LEWIS[8]

Research work on the effect of surface finish on friction and lubrication has been carried on for some time in the engineering laboratories of the Chrysler Corporation. It is very gratifying to find that, in general, the results reported in this paper are in excellent agreement with the work done at Chrysler. The work of both laboratories shows that higher loads can be carried on higher-quality surfaces, and that, further, the better the surface the greater the rate of improvement in load-carrying ability as the surface is made smoother.

As a result of their tests, the authors state that babbitt when used as a bearing surface is relatively insensitive to changes in finish of the mating surface. It is true that in the range of finishes employed (1 to 10-μ in. runs), the performance of a babbitt bearing is not so greatly affected by shaft finish as is that of harder bearing materials. The writer has found, however, that with finishes of the order of 50 μ in. on the mating surface babbitt bearings show greatly reduced performance. For best results with babbitt, as well as with other bearing materials, it is essential to provide good shaft finishes.

The introduction of the circumferential profilometer reading seems rather curious. It is well known that the profilometer has a definite upper limit to the length of irregularities in the direction of motion of the tracer to which it will respond. On a surface in which the finish marks are predominantly in one direction, a reduction in profilometer reading in this direction ordinarily means only that the irregularities are too long to be measured, and does not mean that there is a reduction in the average height of the irregularities in this direction. The change in profilometer reading, as the measurement is made first perpendicular and then parallel to the finish marks, would presumably have some relation to the length of the finish marks, and this may be the reason why the incorporation of the circumferential measurement improved the correlation between test results and profilometer readings.

The authors' demonstration of surface changes during wearing-in is interesting. It has been our experience that running-in is associated primarily with the elimination of irregularities longer than can be measured readily with a profilometer. These irregularities, or waves, are usually of greater height than the surface roughness, and they must be worn down to a common level before the full ability of the surface is realized. If a machined surface is given a few rubs with a honing stick or similar rigid abrasive, the presence of these waves will usually be clearly revealed. The wearing down of these waves depends upon the roughness of their tops. It has been shown (references 2 and 6 of the paper) that machining produces a layer of unsound metal which is comparatively easy to remove. The thickness of this layer depends upon the method of machining and on the roughness of the surface produced, being large for heavy operations such as rough-turning and grinding, less for ordinary finishing operations, and very small for such operations as superfinishing and hyprolapping.

If a surface is very smooth with no disturbed layer, but wavy or subject to distortion when placed in service, it may be difficult to wear-in properly. If it is too rough, it is liable to seizure during run-in, or to such a large wear that its functioning is impaired. If waves or distortion cannot be avoided, it is best to leave only enough roughness and its associated disturbed layer to permit wearing to the proper contour. However, the best surface is one which has no waves, is smooth and has no disturbed layer to give large initial wear. The importance of this point is illustrated by a test carried out in the Chrysler Laboratories in which the load-carrying ability of an extremely accurate superfinished surface was reduced by a factor of 12 when a wave 0.0005 in. deep was introduced in it. It is one of the great advantages of the Chrysler superfinish process that, when properly applied, it tends to correct any waviness due to previous finishing operations as well as to reduce the surface roughness to a low value.

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[6] Chief Metallurgist, International Machine Tool Corporation, Elkhart, Ind.

[7] "How Smooth Should a Bearing Surface Be?" by E. L. Hemingway, *Iron Age*, vol. 149, January 8, 1942, pp. 40–45.

[8] Engineering Division, Chrysler Corporation, Detroit, Mich.

This theory as presented fits in very well with the data given by the authors. For the surfaces upon which a disturbed layer could be expected, the ratio of the final to the initial load as given in their Table 4 averages about 140 per cent; for the fine hyprolapped surface on which very little disturbed layer is expected, it is 104 per cent. The presence of the disturbed layer allows a proper contour to be obtained more readily, and a greater improvement in performance results than in the case where no disturbed layer is available to allow rapid initial wear.

Comment by L. S. Martz[9]

In our opinion, the pre-wearing-in of the bearing specimens at the load, speed, and lubrication used in all of the authors' tests provides a functionally generated common denominator for equitable comparison of the different finishes being studied. It avoids the usual assumption that machine processing alone can reproduce completely comparable and equivalent surface quality and accuracy on surfaces of test specimens. Since any bearing combination involves the metallurgical and mechanical interaction of at least two metals and an oil, this practice also tends to equalize the lubricating quality of the oil in this comparison.

We find the results and conclusions submitted by the authors to be compatible with many of our own observations and studies, as related to mechanically processed surface finishes in the range from 1 to 10 profilometer microinches. For example, we have found that bearing combinations of like materials are relatively more sensitive to surface-finish characteristics than unlike combinations. Recently the conviction has been advanced[10] that, in bearing combinations of like material having poor antiscore qualities, the maintenance of fluid-film lubrication requires either changing the chemical or physical composition of surfaces or providing better control of lubrication supply. In exploration of the latter methods, evidence now exists (details of which the writer regrets may not be reported for some time) that a favorable type and quality of surface finish can be generated and used to make steel on steel an advantageous combination for some uses; even where true fluid-film lubrication is deemed impossible.

This development comprises controlled physical dissimilarity between the mating surfaces, just as similar controlled dissimilarity has been adopted for unlike materials in machine-tool bearings. Proceeding through unlike combinations, from steel on iron to steel on babbitt, we have found surface finish and lubrication to be relatively less critical as resistance to friction increases.

It is our conviction that the generation and maintenance of geometric accuracy is the most important requirement for preventing failure of any type or degree in any kind of surface finish. It is our belief that many of the apparent discrepancies in failure of bearing surfaces which have been reported in the literature, reflect either macro- or microgeometric deformations caused by unfavorable design, assembly, or dissipation of heat, rather than paradoxical characteristics of surface quality. In our opinion, the pre-wearing-in of these bearing specimens provides a functionally generated microgeometric accuracy in balance with the load-speed-lubrication ratio, thus eliminating a common variable in similar tests.

We particularly endorse the suggestion of using auxiliary methods of comparing and evaluating surface-finish characteristics; in this case using the product of the axial and circumferential profilometer readings as an indication of seizure resistance. Since scuffing, galling, and seizing are apparently caused by severe contact of temporarily clean areas on surface asperities, it would seem desirable that measurements comprise these characteristics of "area" rather than of "cross section." Many will consider any approach, toward that objective, as a step in the right direction.

We regret that this study has made only casual reference to the influence of scratch pattern, or direction of the surface scratches. We would like to see corroborative investigation of the results reported by Major Schurig.[11] We have reason to believe that this feature will ultimately contribute toward increased control of microgeometric accuracy, and with rapid, uniform distribution of lubrication supply in surfaces where roughness is only a few millionths of an inch in depth. If all bearings, at starting, must rely on boundary lubrication for satisfactory operation as reported by Professor Karelitz,[12] a "co-directional" type of finish would seem to be the most practical method of preventing or minimizing the possibility of bearing-surface failure.

Comment by W. Mikelson[13]

The results given in this paper indicate what performance may be expected under carefully controlled conditions from a bearing made up of one particular kind of bearing material, using one type of lubricating oil under conditions determined by the particular method of test used. The work represents a very good start and can develop into an important general investigation on bearing performance. It is desirable to continue the investigation using different materials, different lubricants, different methods of finishing, and different methods of test.

The journal surfaces investigated varied from 1 to 10 μ in. rms in surface roughness and were all produced by standard methods of lapping, honing, and grinding. Recent work, however, has indicated that very good bearing performance can also be obtained from surfaces which are considerably rougher. One example of this is an extremely rough-ground surface, sandpapered to flatten off the high spots, which has been said to work well in automobile-engine bearings. Another example is a surface made by first finishing smooth then etching chemically to produce depressions in the surface. An advantage of a bearing having a rough major contour with the top peaks flattened off is that the voids can act as oil reservoirs and retain the oil over the greater portion of the bearing surface longer than is possible with an extremely smooth finish where large bearing pressures are present.

For example, the Schenectady Works Laboratory of the General Electric Company compared a normal ground and polished journal of soft steel (18 μ in. rms roughness) with a similar journal that had been grit-blasted (60 μ in. roughness). The smooth bearing seized at 8500 psi load and the grit-blasted journal withstood 28,900 psi load without seizing. This test, with a $^{1}/_{4}$-in-diam shaft and split bearing, is not representative of service conditions, but it suggests that the smoothing and work-hardening effects of grit-blasting may be helpful in some cases.

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[9] Director, Technical Publicity, Micromatic Hone Corporation, Detroit, Mich.

[10] "Some General Aspects of Rubbing Surfaces," by A. F. Underwood, Proceedings of the Special Summer Conferences on Friction and Surface Finish, Massachusetts Institute of Technology, Cambridge, Mass., June 5–7, 1940, pp. 5–12.

[11] "How Should Engineers Describe a Surface?" by O. R. Schurig, Proceedings of the Special Summer Conferences on Friction and Surface Finish, at Massachusetts Institute of Technology, Cambridge, Mass., June 5–7, 1940, pp. 141–155.

[12] "Boundary Lubrication," by G. B. Karelitz, Proceedings of the Special Summer Conferences on Friction and Surface Finish, at Massachusetts Institute of Technology, Cambridge, Mass., June 5,–7, 1940, pp. 102–111.

[13] General Engineering Laboratory, General Electric Company, Schenectady, N. Y.

In general, however, our experience indicates that, with suitable lubricating methods, the smoother the surface the higher the load that can be carried.

COMMENT BY E. A. RYDER[14]

The authors have given us some new light on bearing problems, but they have also turned up enough new problems to keep them busy for some time to come.

The writer would amend the statement early in the paper which says that seizure is a serious problem in certain kinds of bearings. It is true that it is a problem in bearings of certain materials, but materials are available for aircraft-engine bearings which are not sensitive to failure of lubrication, and which will stand a tremendous amount of punishment.

Information is needed as to the permanence of very fine journal finishes, in aircraft engines, for instance. It seems unlikely that a crankpin finished to 1 or 2 μ in. would remain as smooth as this after a long period of use. More or less sand is ingested into the engines, and the finish may be found to stabilize at a considerably rougher value. The writer regrets that he has no data on this at the moment.

Have the authors tested the type of finish produced by rough-grinding followed by a polishing operation which leaves a smooth surface with rather deep short scratches in it? There is a further question about the use of a nitrogen atmosphere. The oxidation of engine oil which occurs in normal use affects its lubricating properties, generally improving them, and this would be expected to make a difference with the test results. Comment on this would be appreciated.

Have the authors tested a ground finish of say, 5 to 10 μ in. followed by buffing instead of sandpapering? This is a type of finish sometimes applied to hardened journals.

The experiments on lapped surfaces are very interesting and should be of considerable value to constructors.

COMMENT BY D. E. WILLIAMSON[15]

We are in good agreement with the authors of this paper in their findings that specification of roughness alone does not completely describe the quality of a bearing. It has been suggested many times that at least two pieces of information are essential in the specification of surface finish. One is the "roughness of the surface," while the other is the "arrangement of the marks" left by the finishing operation. In general, the terms cylindrical grind, turn, hone, and the like, would sufficiently describe the arrangement of the finishing marks. To conform with engineering practice and facilitate putting this information on blueprints, a system of symbols has been devised. These symbols indicate the arrangement of the roughness pattern and are combined with the allowable roughness in microinches root mean square.

The tests showing that the truly cylindrical (ring-lapped) surface produced superior results (when furnished with the proper finish) should not be overlooked. Obviously, if the load on the bearing is to be carried by the roughness peaks, these peaks must be located accurately along the ideal surface.

If, in the effort to obtain smoothness, geometrical accuracy is lost, the results are likely to be contrary to expectations. This test may well suggest an explanation for cases in which rough surfaces give better performance than smooth ones.

It is suggested that the authors of this paper replace the term "scratch direction" with another term. This is suggested inasmuch as the proposed "Standard of Surface Roughness" (B-46) defines a scratch as an "irregularity which occurs only at one place or at relatively infrequent and widely varying random intervals on a surface." The word "lay," suggested by Abbott as a means of describing the arrangement of finish marks, has the advantage of being short and easily understood.

From the point of view of the designer of the measuring instrument, the concept "direction of roughness" has no meaning. The hills and valleys that make up the roughness of a given piece will not be altered by changing the direction in which the measuring instrument is moved on its surface. The State of Pennsylvania can be described by saying that it has a mountain range about 2000 feet in height which runs north and south. The traveler can avoid these peaks by traveling in the north and south valleys, but the topographer should not stay in the valleys if his maps are to be of general value.

A measuring instrument, then, should give information of general usefulness. In this case it should measure the vertical dimensions of as many hills and valleys as possible. The information that the hills and valleys run in a particular direction can be given as additional information as to the suitability of the surface for its intended use. The profilometer is such a measuring instrument, and its reading is specifically a dimension and not an absolute measure of surface quality (which contains other factors such as materials, hardness, direction of roughness, freedom from waves, flaws, etc.).

In the case of the profilometer, one of the design problems was to make the instrument measure only the roughness, and effectively exclude contributions to the reading due to waviness and flaws. This is done by limiting the low-frequency response of the instrument so that the contribution due to waves will not pass the vacuum-tube amplifier at ordinary tracing speeds. As roughness consists of irregularities having peak-to-peak distances of about $^{1}/_{32}$ in. or less (and tracing speeds run about $^{1}/_{2}$ in. per sec), the low-frequency cutoff was set at 15 cycles per sec. Below that frequency no voltage passes the amplifier. On ordinary surfaces the principal irregularities are of such width that they generate 100 to 200 cycles per sec, which is well within the range of the amplifier.

An instrument designed thus will give accurate readings when the tracing device is moved across the irregularities. As the ratio of length to width of the irregularities is in the neighborhood of 20, attempting to trace parallel to the valleys will generate $^{1}/_{20}$ of the frequency. The principal irregularities will generate only 5 to 10 cycles per sec and will consequently not be measured. Measurements taken in the direction of the irregularities will consist of measurement of "the roughness of the principal hills and valleys." Note that the foregoing applies only if tracing is done accurately parallel to the roughness. Crossing the roughness at only a slight angle will generally produce sufficiently high frequencies to give good readings.

In the present case, measurement parallel to the roughness has been used to "weight" the transverse (axial) readings. It is doubtful if this method can be relied upon in all cases. The adoption of the method will be desirable if it proves to be of value.

AUTHORS' CLOSURE

It is gratifying to note that, in general, the commentators are in agreement with the results of our work. The major debatable point seems to be the advisability of making roughness measurements parallel to the "lay."

It must be admitted that the technical limitations of roughness-measuring devices were not considered when readings parallel to the lay were first made, or none might have been taken. Later, when it was established that the product of this unusual roughness reading with the conventional one was a good indicator of bearing performance, there seemed to be no reason for discontinuing the practice. The roughness product has enabled us to correlate the bearing performance of widely different types of abrasively finished surfaces.

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[14] Consulting Engineer, Pratt and Whitney Aircraft, Hartford, Conn.

[15] Manager, Physicists Research Company, Ann Arbor, Mich.

Instruments for measuring roughness generally measure the depth of scratches, and this of itself cannot be the important factor in such bearing performance as we are considering. The evidence points to the fact that a measure of contact area is needed, as Mr. Martz suggests. However, surfaces finished with abrasives have characteristics so much like one another that a profilometer value, obtained in a given direction along a surface, may be related to the length of contact that the surface will have in that direction with a mating surface. In such a case, the product of two profilometer values, taken along the direction of motion of the surface and at right angles to it, would be related to the product of the contact lengths in those two directions, i.e., to the area of contact.

It is believed that there need be no fears that the roughness reading parallel to the lay will be a difficultly measurable and erratic number for surfaces finished with abrasives. We have found that, with no extraordinary precautions, duplicate roughness readings on the same sample agree at least as well as duplicate roughness readings of the conventional type. This indicates that no unusual care is necessary in lining up the finish marks and the movement of the tracer point, and there would seem to be no direction at which the roughness drops to zero. Furthermore, roughness readings parallel to the lay, taken with two different types of commercial roughness-measuring instruments, agree as well as do readings with the same instruments perpendicular to the lay. Since the two instruments differ considerably in their low-frequency response, it appears that coarse roughness irregularities are not the major factor being measured.

When taking Brush analyzer readings parallel to the lay on cylindrically ground specimens, the arm of the instrument should be clamped in position at right angles to its direction of motion. The tracer point and the shoe thus ride over the curved surface together at substantially the same horizontal level when their mean position is at the high point of the specimen. With this arrangement, difficulties of variable contact do not occur. However, in the case of the profilometer its construction is such that an experienced operator is able to get reasonably satisfactory readings parallel to the lay on our 2-in-diameter specimens, with the length of the profilometer tracer either perpendicular to or in line with its direction of motion.

To be specific, the following results were obtained on one of the cylindrically ground Amsler 2-in-diameter specimens having axial roughness of 4.6 to 5.2 rms microinches:

Instrument and method	Circumferential roughness parallel to lay
Brush rms meter; arm moved sidewise*	2.6 to 3.6
Profilometer; tracer moved sidewise	3.0 to 3.5
Profilometer; tracer moved lengthwise	3.5 to 4.0

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*With the Brush arm moved lengthwise unsatisfactory readings were obtained that varied between 8 and 50, due to variable contact with the specimen surface.

With regard to Mr. Burwell's comment on the loose-abrasive-lapped surfaces, it has been found by further study of the specimen surfaces after wearing-in that the contact area of these specimens showed waviness. This probably remained from prior operations, and our findings for the lower seizure resistance of this class of surface may have been influenced by their waviness rather than by other characteristics. We quite agree that the results from a turned surface would most likely not correlate with the roughness product. We would advocate the use of this product only for abrasively finished surfaces.

With respect to Mr. Burwell's observations on a metal-sprayed steel surface, some work done in the Research Laboratories of the Norton Company indicates that such surfaces are difficult to grind satisfactorily with an alundum wheel, such as performs well on the solid metal. Mr. Burwell's assumption that the load-bearing portion of his 60-μ in. surface had a roughness of only 15 μ in. may, therefore, be in error. Sprayed metal also is likely to be badly oxidized throughout, and this may have been a contributing factor toward reducing its load capacity and causing it to run hotter.

Mr. Gravley's comments may be interpreted as suggesting that waviness (defined by the A.S.A. Proposed Standard of Surface Roughness as of wave length greater than 0.040 in.) may influence friction and seizure characteristics, although not shown by the meter reading of roughness-measuring instruments. With the exception of waviness on the loose-abrasive-lapped specimens, as just discussed in connection with Mr. Burwell's comments, there was no indication that waviness was present to affect any of the other results. Also, the Amsler specimens had a 2 in. diam, and the curvature was insufficient to affect any of the root-mean-square meter readings or Brush analyzer charts of the surfaces, when the readings were taken with the arm of the instrument moving at right angles to its length.

Geometric accuracy is indeed important, as brought out particularly by Messrs. Hemingway, Martz, and Williamson. Effects of scratch direction and waviness are being included in the continuation of our studies.

We agree with Mr. Lewis that babbitt is sensitive to finishes as rough as 50 μ in. Mr. Lewis' results on waviness are interesting and confirm our own opinion that small amounts of waviness in the microinch range may have a large effect.

It should be kept in mind that the first and third types of surfaces mentioned by Mr. Mikelson are both being used for some other purpose than to resist the kind of seizure being discussed. The first, i.e., the Buick plateau-and-valley finish, was developed by General Motors engineers to prolong the life of babbitt connecting-rod bearings operating under conditions of hydrodynamic lubrication, by reducing the tendency for fatigue failure of the babbitt bearing metal, and not because of any considerations relating to seizure resistance.

The over-all roughness of the plateau-and-valley type of surface reads some 50 μ in., as measured with a profilometer, the reading being largely influenced by the roughness of the deep valleys that are residual from the extremely rough prior grind. But the actual load-carrying areas are the plateaus having a sandpaper finish of some 5 or 10 μ in. Therefore, it is not correct to say that a very rough surface is carrying high loads satisfactorily. This becomes a special case which has to be considered as a duplex surface having two different superimposed degrees of roughness, produced by two different machining operations. It is not at all like the usual case where we attempt by each subsequent machining operation in a sequence, to remove all traces of the prior surface and thus leave a single type of surface finish which is characteristic only of the final operation.

The third surface mentioned by Mr. Mikelson, i.e., the grit-blasted surface was tested in an Almen film-strength testing machine where galling, not seizure of the type discussed was being tested. The measuring and interpretation of such tests, and also the test conditions, are so different from those prevailing in the Amsler machine tests under discussion that correspondence should not be expected for the test results.

With respect to Mr. Ryder's comments on the stabilization of aircraft crankpin surfaces at finishes considerably rougher, due to use, than the initial 1 or 2 μ in. figures, should we not also take into account the minute accompanying changes that have occurred in the fit characteristics between the mating surfaces?

In reply to Mr. Ryder's question, the "Buick" type finish has been tested, and the results are about what would be expected from the finish on the plateaus when allowance is made for the extent of the valleys. Buffed surfaces have been tested, and found to be slightly better than the surface to which the buffing was applied. Nitrogen atmospheres were used during our tests to prevent the oxidation which otherwise changes conditions during the testing and yields an ambiguous result. Qualitatively similar results are obtained with oxidized oils.

R. W. DAYTON,[16] H. R. NELSON,[16] L. H. MILLIGAN.[17]

Failure of S.S. "Schenectady"

TO THE EDITOR:

The break in the oil tanker, *Schenectady*, at the Swan Island yard, while standing at the dock and after a trial run, has caused much discussion. This failure has been attributed to a number of causes, among which are the following: shrinkage stresses in the welds, earthquake, silt collecting under the boat, a wind blowing from the side, and improper loading. The writer has not so far heard that it has been attributed to the machination of some perverse demon.

This failure is important because there is very little doubt that it is possible for the same failure to occur in many other ships. We, therefore, must evaluate what happened accurately.

Let us first consider the foregoing causes. We can be sure that the so-called locked-up stresses of welding did not cause the break. These stresses obviously decrease continuously as soon as the weld is cold. Such stresses would, of necessity, cause failure immediately or not at all.

If improper loading would cause failure it certainly would not cause it at the dock—it would have caused it when the ship was in a seaway during its trial trip.

We probably can also rule out the other suggestions which have been made which are even more fatuous.

In arriving at the actual cause, the following fundamental fact should be considered. It is possible to have unequal expansion of the shell of the ship compared to its deck. Since the temperature of water is fairly constant compared to the air when the ship is in cold air, the shell is expanded compared to the deck thus putting a tensile stress on the deck which may be very great. For instance, a difference of 15 F between the shell and the deck will make a relative change of $^3/_4$ in. in the length of the deck and the shell of the ship. Normally the deck would stretch by this amount without further damage. There are conditions which would not allow such a happy outcome.

If there is an incipient tear started at the longitudinal center of the deck, then all the stretch will take place at this point. If there is an abrupt change of section of the deck the same tendency will result. If the stretch forced by this unequal expansion takes place in this one point, rupture must result. This is obviously what happened in all the cases of all known failures.

Obviously, all ships so made are threatened with the same failure if all the same unhappy circumstances should take place. However, this can only occur when the temperature of the deck is relatively cooler than the temperature of the shell. Therefore, if the ship has gone through one winter without failure, the chances of its failing later are extremely remote.

There are three suggestions as to how the foregoing possibility can be entirely eliminated. First, obviously, is to make the deck stronger relatively than the shell so the deck will bend the shell instead of the shell's stretching the deck.

The second suggestion would be to put a wrinkle in the deck so that the pull mentioned will straighten out this wrinkle before it puts any great tensile stress on the deck.

Third, and this is more reasonable than the other two, is to put the deck under a sufficient compression at time of construction so that under any difference of temperature to which the ship will be exposed in service, the deck will not be put under a tensile stress which will approach its minimum strength at any point. This can easily be done at the time of welding the deck together in the center section by wedging it apart at the time.

Of course another obvious answer is, after construction to expose the ship to maximum temperature difference between shell and deck, allowing it to break, which will relieve the stresses, and then welding it up in that position. No further break could occur under this procedure. It seems, however, this would be a senseless approach to the solution.

J. F. LINCOLN.[18]

Euler's Number

TO THE EDITOR:

The writer was greatly interested in Professor Thomas' discussion[19] on this subject, and agrees with his suggestion tha tthe dimensionless group $(\rho v^2/p)$ should have a name. However, the writer has been calling it the reciprocal of "Newton's number," a designation which has already been used.[20]

The writer believes it merely complicates the situation to give a new name to something already identified. Simply inverting the expression scarcely justifies changing its name, since it still represents the same relation between the same basic quantities. For the same reason, he has regretted the use of different names for the Cauchy number and the Mach number, when one is merely the square of the other. The Froude number is usually defined as v^2/gl (as it is customarily used) but is sometimes expressed $v/\sqrt{gl}$. Nevertheless, no new name has been attached for this merely formal change. Hence, it is believed to be better to utilize Newton's name for the group $(\rho v^2/p)$ either in this form or in its reciprocal.

Another point upon which the writer does not fully agree is that this group serves as a criterion of cavitation. It would seem that this is true only if p is defined not as the absolute pressure, but as the excess of pressure over the vapor pressure of the fluid.

LEWIS F. MOODY.[21]

TO THE EDITOR:

The following comment is offered in reply to the two questions raised by Professor Moody:

An objection to the use of the term "Newton's number" for the dimensionless group $p/\rho\, v^2$ (or its reciprocal) is the existence of a tendency among hydraulicans to use the term "Newton's number" in a much broader sense as a designation for the group $f/l^2\, \rho\, v^2$ (or its reciprocal); that is, the ratio of any force f acting on a fluid element to the "inertia force" of that element.

The term $\rho v^2/p$ is a criterion for cavitation in natural-scale models, provided the term "natural-scale" is understood to include the chilling of the model fluid until its vapor pressure is reduced in proportion to the linear scale. From this point of view, an ordinary cavitation test on a model using water at room temperature involves the use of a distorted pressure scale.

HAROLD A. THOMAS.[22]

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[16] Battelle Memorial Institute, Columbus, Ohio.

[17] Norton Company, Worcester, Mass.

[18] President, The Lincoln Electric Company, Cleveland, Ohio. Mem. A.S.M.E.

[19] "Euler's Number," Letter to the Editor, by H. A. Thomas, MECHANICAL ENGINEERING, March, 1943, pp. 210–211.

[20] "Handbook of Engineering Fundamentals," edited by O. W. Eshbach, John Wiley & Sons, Inc., New York, N. Y., 1936, section by Ernst Weber.

[21] Professor, Hydraulic Engineering, Princeton University, Princeton, N. J.; also Consulting Engineer, Baldwin Locomotive Works, Philadelphia, Pa., and Worthington Pump & Machinery Corporation, Harrison, N. J. Mem. A.S.M.E.

[22] Professor of Civil Engineering, Carnegie Institute of Technology, Pittsburgh, Pa.

Use of Plywood in Aircraft

COMMENT BY R. J. NEBESAR[23]

Concerning various matters dealt with in this paper[24] the writer offers the following comments:

Adhesives and Their Application. So far we have had very good results with cold-setting urea glues in assembly work, even though this adhesive is not boilproof. However, it is really difficult to explain why the boiling-water test should be applied to wood structures, or for that matter to any airplane structures.

From experience with wood constructions under extreme temperature variations, and from the record of performance of older-type wood airplanes such as Lockheed Vegas, Orions, or the Fokkers, etc., the writer does not seem to recall any doubts concerning the ability of these structures to stand up under such service conditions.

Referring to the crazing tendency of such glues our experience shows that, provided the glue line is not very thick, i.e., not over 0.040 in. thick, this difficulty does not exist.

Special Fabrication Processes:

(*a*) Even if metal molds are to be used, we believe that the effect of changes on tooling would not be more accentuated in wood construction than in metal construction.

(*b*) As explained in a paper[25] by the writer, under controlled conditions, hot resins will retain entirely satisfactory characteristics over a period of several days.

Plywood Components of Airplane Fittings and Connections:

(*c*) Under this heading, some of the design problems mentioned are being handled. However, instead of compreg or densified woods at concentration points, we are using higher-density woods, such as maple and hickory, which do not present the gluing problems.

(*d*) It is true that there are multiple parts in ribs, but this is also the case in metal construction. However, gluing makes the assembly of such parts a simple process. If properly designed, there are no difficult fitting problems; diagonals and verticals are assembled with clearance against the cap strips, with the gussets taking care of the distribution loads.

Airplane Construction and Assembly in Relation to Plywood. The principal difference between metal and wood aircraft fabrication lies in the fact that, if a proper design for wood is developed, there will be fewer parts in wood construction than in metal. Also, it is believed that time will be saved because gluing is a simpler operation than riveting.

Structural Theory. There is no question but that wood, or plywood, offers much greater local stiffness, which allows us to use much larger unsupported panels than in metal construction with fewer stringers, wider rib spacing, and the like. Of course, in some special cases, it may be possible to design pure shell or monocoque structures.

COMMENT BY MELVILLE K. WEILL[26]

Taking advantage of the natural characteristics of wood, the company with which this author is connected, has developed a construction which comes closer to achieving the ideal or true monocoque, than has as yet been accomplished by the use of metal or other wood constructions.

The material used is composed of a relatively thick balsa core, sandwiched between two thin plywood sheets. Such construction utilizes to the greatest extent the high strength-weight ratio of wood, likewise allowing for the creation of a high stiffness factor with a minimum increase in weight. This permits the building of structural parts with elimination of spars and ribs in surfaces and reinforcing stringers in fuselages.

Many other desirable qualities become evident, such as a sturdy surface, damping of vibration, insulation against sound, and the transfer of heat or cold, also retarding the formation of ice.

Holes from gunfire are clean with no flowering effect, as contrasted with the effect on metal. What is more, the damage is greatly reduced in this type of construction, since for all practical purposes the skin can be considered as uniformly loaded.

Stoker Maintenance

COMMENT BY A. W. THORSON[27]

The author[28] has wisely summarized the basic causes of high stoker maintenance at a time when operating engineers may neglect fundamentals owing to pressure of duties.

The writer would emphasize further the troubles which may be caused by coal-size segregation. Poor fires, reduced efficiency, and high maintenance are often corrected merely by correcting segregation in a bunker, conveyer, or storage pile. At the first Joint Fuels Conference in Pittsburgh in 1937, D. R. Mitchell reported his work on this subject.[29] Every plant engineer should review this now and assure himself that he is overlooking no possible improvement.

Wet coal can produce high maintenance by causing sticking in bunkers and hoppers, and feed pipes. As a result, the feed to parts of a stoker is irregular or intermittent. This often causes burnouts. Such troubles may be impossible to correct, but they can usually be alleviated by such things as selection of dry portions of storage piles, drying coal wherever possible, and watching the coal-feed spouts to insure proper flow.

The burning of tuyéres and side plates has frequently been traced to banking periods. When airflow through a fuel bed is stopped completely, the hot coke heats the iron. The writer has examined stoker windboxes under such conditions and found the entire area of tuyéres and supports a cherry-red color. Avoid as many banked hours as possible. Frequently, rather than bank some units over night, it is possible to operate all units at low ratings. Such a schedule has reduced burnt iron in some plants.

Under the heading "Traveling-Grate Stokers," the author reports that an increased percentage of undersized fuel will cause a loss in capacity and efficiency. Within limits this statement is true of all types of stokers and should be borne in mind by all stoker operators.

AUTHOR'S CLOSURE

It is gratifying to have a man of Mr. Thorson's experience with large stokers support the suggestions of the author in avoiding high maintenance and retaining good combustion.

Too little attention seems to be paid to the question of size segregation caused by the handling systems until after troubles develop. It would seem possible to originally design the handling system to avoid such troubles.

If the fundamental requirements of burning coal on stokers are kept in mind, maintenance can be reduced to a minimum.

A. R. MUMFORD.[30]

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[23] Chief Engineer, Universal Moulded Products Corporation, Bristol Aircraft Division, Bristol, Va. Mem. A.S.M.E.

[24] "Problems in the Use of Plywood in Airplane Construction," by Alexander Klemin, MECHANICAL ENGINEERING, February, 1943, pp. 105–109.

[25] "Molded Plastic-Bonded Veneers and Wood in Aircraft Construction," by R. J. Nebesar, MECHANICAL ENGINEERING, March, 1943, pp. 197–201.

[26] President, Skydyne, Inc., Port Jervis, N. Y. Mem. A.S.M.E.

[27] Carnegie Institute of Technology, Pittsburgh, Pa. Mem. A.S.M.E.

[28] "Avoiding High Stoker Maintenance—Retaining Good Combustion," by A. R. Mumford, MECHANICAL ENGINEERING, February, 1943, pp. 119–124.

[29] "Segregation in the Handling of Coal," by D. R. Mitchell, American Institute of Mining Engineers, Tech. Pub. no. 846, 1937.

[30] Combustion Engineering Company, Inc., New York, N. Y. Fellow A.S.M.E.

Wartime Fuel Problems

COMMENT BY R. C. RASMUSSEN[31]

The writer is wholly in accord with the views expressed in this paper,[32] i.e., precautions to prevent coal-storage fires, and boiler-room-equipment recommendations best suited to meet our wartime fuel problems. From experience gained in the field we, as engineers, can render further valuable assistance by making careful analyses of these industrial fuel-burning problems as they are encountered.

One of our immediate problems throughout the Midwestern states has been the necessity of producing additional boiler capacity. In many cases no priorities are available and if they were, deliveries would still be a matter of many months.

The general misapplication of coal both as to quality and size for a given unit is one of the most common faults found by the writer; for instance, the attempted use of lower-rank coal on units with high heat release and heavy combustion rates. Utilization is a second factor of equal importance, and one which is also commonly neglected. A careful study of combustion rates, heat releases, and load conditions will determine both rank and size of fuel required for a given stoker or boiler.

The writer has observed installations with four units on the line which were unable to carry the load. By correcting the size and type of fuel, we have been enabled to carry the same load without difficulty on three units with the fourth as a stand-by. In another instance, a central heating plant fully equipped, with complete auxiliaries for combustion control was unable to carry the load on its full complement of these units. A careful study of load conditions, combustion rates, proper application and utilization of fuel resulted in carrying the same load on a single unit.

From these and many other examples, it is evident that a great deal can often be accomplished in providing additional capacity without expenditure or delay occasioned by the purchase and installation of new equipment. The services of qualified combustion engineers are available throughout the country for the purpose of making such studies and recommendations. These men are familiar with the various types of solid fuel available and how best to utilize them in order to meet load conditions and still obtain economical steam costs. The writer would strongly recommend that the consumer avail himself of their services.

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[31] Sales Engineer, Bell & Zoller Coal Company, Chicago, Ill.

[32] "Meeting Wartime Fuel Problems," by Ollison Craig, MECHANICAL ENGINEERING, October, 1942, pp. 697–702.

A.S.M.E. BOILER CODE

Interpretations

THE Boiler Code Committee meets monthly for the purpose of considering communications relative to the Boiler Code. Anyone desiring information on the application of the Code is requested to communicate with the Committee Secretary, 29 West 39th St., New York, N. Y.

The procedure of the Committee in handling the cases is as follows: All inquiries must be in written form before they are accepted for consideration. Copies are then sent by the Secretary of Boiler Code Committee to all of its members. The interpretation, in the form of a reply, is then prepared by the Committee and is passed upon at a regular meeting.

This interpretation is later submitted to the Council of The American Society of Mechanical Engineers for approval after which it is issued to the inquirer and published in MECHANICAL ENGINEERING.

Following is a record of the interpretation of this Committee formulated at the meeting of February 19, 1943, subsequently approved by the Council of the Society.

ANNULLED CASES

Case No.	PARAGRAPH REVISED
840	U-20(*a*)
903	Inquiry withdrawn
948, 949	P-102(*h*), U-68(*h*)
951	Rules for welding boilers of locomotives
960	P-112
966	Tables P-6, U-3

CASE No. 979

Add the following as item (8):

(*8*) In the determination of thicknesses for internal pressure of ferrous tubes and pipes, the design stresses in Tables U-2 and U-$2^1/_2$ may be multiplied by 1.25 for use in the formula in Par. U-20(c).

CASE No. 993

(Interpretation of Par. U-72f)

Inquiry: In order to fill an urgent need, may the proposed revision of Par. U-72(*f*), covering bending stresses in welded joints, as published in the January, 1943, issue of MECHANICAL ENGINEERING, be made effective immediately?

Reply: Since no adverse comment has been received and no changes are indicated in the proposed revision of Par. U-72(*f*), it is the opinion of the Committee that the following revised form of this paragraph may be used in place of the present form pending the issuance of the customary schedule of revisions in the form of addenda sheets:

"(*f*) The design of welded vessels shall be such that if bending stresses are brought directly upon a welded joint, the design shall be analyzed to keep the maximum stress within the allowable limits, and complete weld penetration through the thickness of the joined plates shall be obtained, with added fillet welds where necessary to reduce stress concentration. Corner joints with fillet welds only shall not be used unless the plates forming the corner are properly supported independently of such welds."

CASE No. 994

(In the hands of the Committee)

CASE No. 995

(Interpretation of Fig. UA-3)

Inquiry: Fig. UA-3(10) in the Code specifies a fillet weld with a minimum throat dimension of $0.7g_0$ at the back of the flange. A complete stress calculation is required for this type of flange per Par. UA-21(*a*)(2) and when this large fillet weld is not needed for strength its requirement works an undue hardship upon designers wishing to use this detail. May a fillet weld with a minimum leg dimension of $0.25g_0$, but not less than $^3/_{16}$ in., be used?

Reply: It is the opinion of the Committee that provided the flange stress calculation meets the requirements of Pars. UA-23(*a*) and UA-24(1), the fillet weld in Fig. UA-3(10) made with a minimum leg dimension of $0.25g_0$, but not less than $^3/_{16}$ in., is sufficient to avoid stress concentration at the corner and may be used, or the fillet weld may be machined to a minimum corner and may be used, or the fillet weld may be machined to a minimum corner radius of $0.25g_0$, but not less than $^3/_{16}$ in., as permitted in Fig. UA-3(8).

Revisions and Addenda to Boiler Construction Code

IT IS the policy of the Boiler Code Committee to receive and consider as promptly as possible any desired revision of the rules and its codes. Any suggestions for revisions or modifications that are approved by the Committee will be recommended for addenda to the code, to be included later in the proper place.

The following proposed revisions have been approved for publication as proposed addenda to the code. They are published below with the corresponding paragraph number to identify their location in the various sections of the code and are submitted for criticism and approval from anyone interested therein.

It is to be noted that a proposed revision of the code should not be considered final until formally adopted by the Council of the Society and issued as pink-colored addenda sheets. Added words are printed in SMALL CAPITALS; words to be deleted are enclosed in brackets [ ]. Communications should be addressed to the Secretary of the Boiler Code Committee, 29 West 39th St., New York, N. Y., in order that they may be presented to the Committee for consideration.

Pars. P-17 and U-17. Add the following as (*b*):

(*b*) *Under-Tolerance.* Plate material that is not more than 0.01 in. thinner than that calculated from the formula may be used in Code constructions provided the material specification permits such plate to be furnished not more than 0.01 in. thinner than ordered.

Pars. P-23 and U-20. Add the following as Par. P-23(*j*) and as the last section of Par. U-20(*d*):

Fabricated pipe bends may be made by welding together beveled sections of straight pipe provided:

(1) The angle between the axes of the adjoining sections does not exceed 30 deg;

(2) The thickness is at least $\dfrac{(K - {}^1/_2)}{(K - 1)}$ times the required thickness of the straight pipe to which the bend is joined.

K = ratio of the radius of the bend (from center of curvature to center of pipe) to one half the inside diameter of the pipe.

Par. P-102(*b*) and U-68(*b*). Revise third sentence of second section to read:

The finished surface of the reinforcement may have a crown of approximately uniform amount not to exceed the following:

Plate thickness, in.	Thickness of reinforcement, in.
$^3/_8$ to $^1/_2$, incl.	$^1/_{16}$, maximum
Over $^1/_2$ to 1, incl.	$^1/_{16}$ to $^3/_{32}$
Over 1 thick	$^3/_{32}$ to $^1/_8$

Pars. P-102(*b*) and U-68(*b*). Add the following:

When radiographing a circumferential pipe joint by placing a radium capsule inside the pipe, the penetrameters may be placed on the film side of the circumferential joint provided the manufacturer satisfies the inspector that the technique followed in doing the work is known to be adequate.*

When the radium capsule is placed on the axis of the joint and the complete circumference radiographed with a single exposure, four penetrameters uniformly spaced shall be employed.

*Note: A suggested method for proving the adequacy of the radium capsule method of radiography is as follows:

A preliminary radiograph should be made with a piece of pipe with penetrameters on both the inside and outside. The diameter of the pipe employed in making this proof radiograph should be substantially the same as that of the job in hand, and its wall thickness the practical equivalent of the over-all thickness of the joint to be radiographed, including both backing ring and reinforcement if these are present in the joint to be examined. The radium capsule employed in making this proof radiograph, together with all other items of technique such as the location of the capsule and the time of the exposure, should be the same as employed on the actual job. Each penetrameter should be provided with a marker which will show up clearly on the film and which will indicate the side of the joint on which it is located: *F* for the film side, and *R* for the radiation side.

Pars. P-102(*b*) and U-68(*b*). Add the following to the seventh section (first section at top of page 23 of Power Boiler Code and second section on page 61 of Unfired Pressure Vessel Code):

However, when the X-ray tube is operated at a voltage of 1000 kv or more and the Buckey grid is used on plates 3 in. or more in thickness, the foregoing specifications on technique may be modified to suite the requirements.

Pars. P-102(*b*)(*1a*) and U-68(*b*)(*1a*). Revise the fourth section to read:

There shall be three holes in each penetrameter of diameters equal respectively to two, three, and four times the penetrameter thickness, but in no case less than $^1/_{16}$ in., EXCEPT WHEN GAMMA RAYS ARE USED AS A SOURCE OF RADIATION, THE MINIMUM HOLE NEED NOT BE LESS THAN $^3/_{32}$ IN. The smallest hole must be distinguishable on the radiograph.

Pars P-105(*c*) and U-74. Revise to read:

Unreinforced holes may be machine-cut through welded seams that have been stress-relieved and radiographed. The joint efficiency as well as the ligament efficiency shall be considered in calculating the thickness.

Tubes may be rolled and expanded in such unreinforced holes, or such holes may be threaded, provided that in the portion of the welded joint in which the holes are cut the following additional requirements are met:

(1) The welds have been examined by the magnetic powder method on both sides and found to be satisfactory;

(2) The weld shall contain no slag inclusion or defect longer than $0.15t$ (where t is the thickness of the weld), but in no case greater than $^3/_8$ in.

If either item (1) or (2) is not complied with, the unreinforced holes for threaded connections or for rolled or expanded tubes may not be placed closer tha $^1/_4$ in. to the edge of the fused metal, and no deduction need be made in the maximum allowable working pressure computed for the same tube layout without a circumferential weld.

Par. P-108(*c*) and U-76(*e*). Add the following as (5):

(5) In the case of welded joints in piping and tubing, the width of the heated circumferential band shall be at least three times the width of the widest part of the welding groove but in no case less than twice the width of the weld reinforcement.

Par. P-109(*a*). Add the following as the second section:

The hydrostatic test pressure of the completed unit shall not exceed that provided for in Par. P-329.

Par. P-112(*c*). Revise to read:

(*c*) All circumferential fusion welded joints of parts covered by this paragraph and welded in accordance therewith shall have a double welded butt joint or single welded butt joint made the equivalent of a double welded butt joint (See note in Par. P-101).

(Second section to remain unchanged.)

In welding single welded butt joints, complete penetration at the root is required, which must be demonstrated by the qualification of the process to be used. If complete penetration cannot otherwise be secured, the process must include a backing ring or equivalent. The depth of weld must be not less than the minimum thickness permitted by the applicable material specifications for the particular size and thickness of pipe or tubing used.

Backing rings may be left in place or removed as desired. Backing rings which are to be removed may be of any size, shape, or material, but if left in place they must be properly secured to prevent dislodgment and shall have a contour on the inside to minimize the restriction to flow, if required, and be of such inside diameter as to permit the passage of a tube cleaner where such cleaner may be used.

If the pipe or tube wall is recessed for a backing ring, the depth of such recess shall be so limited that the remaining net section of the finished joint is not less than the minimum required thickness.

The joints of all parts welded under the provisions of this paragraph shall be stress-relieved in accordance with Par. P-108, except that those in carbon steel not over $^3/_8$ in. nominal thickness and in carbon molybdenum material with carbon not exceeding 0.20 per cent and not over $^3/_8$ in. nominal thickness need not be stress-relieved. When welded joints in tubes or pipes are not stress-relieved, the procedure qualification must be made under the same conditions but the operator-qualification test may be made on either stress-relieved or non-stress-relieved samples. No radiographic examination of welded joints will be required, except as provided in (*a*)(6).

Fig. P-7. To be deleted.

Pars. P-195(*a*) and U-36(*a*). Revise the definition of "*E*" for seamless shells to read: E = for seamless [shells with integral] heads = 100 per cent

Pars. P-195(*d*) and U-36(*d*). Replace Pars. P-195(*d*), (*b*), (*o*) and U-36(*d*), (*b*), (*n*) by the following:

(*d*) Except as otherwise provided for in (*c*), (*g*), and (*n*) (U-36 *c*, *g*, and *m*), all openings which require reinforcement, placed in a head dished to a segment of a sphere, or in an ellipsoidal head, or in a full-hemispherical head, including all types of manholes except those of the integral flanged-in type, shall be reinforced in accordance with the rules in Par. P-268(*g*) (U-59*g*). In the application of those rules the opening shall be treated as though it were in a shell:

(1) Of the same outside diameter as the outside diameter of the flange of the head;

(2) Of the same material as that in the head and for the same working pressure.

The required thickness "*t*" of the shell, which is needed in Fig. P-36 (U-6) and Par. P-268(*g*) (U-59*g*) for computing the amount of reinforcement required, shall be determined from the formula in Par. P-180 (U-20), using $E = .90$ (this is the method specified in Par. P-268(*g*) (U-59*g*)), except that one half the computed value may be used for "*t*" when the opening is in a full-hemispherical head. The actual thickness of the head shall be taken as the value of "*m*" referred to in Fig. P-37 (U-6) and Par. P-268(*g*) (U-59*g*).

When so reinforced, the thickness of such a head may be the same as for a blank unstayed dished head.

PAR. P-195(*i*). A typographical error has been discovered in that when this paragraph was revised in 1938, the present (*i*) should have been deleted and (*h*) as it appeared in the 1937 edition should have been retained. This section reads:

When heads are made to an approximate ellipsoidal shape, the inner surface of such heads must lie outside of and not inside of a true ellipse drawn with the major axis equal to the inside diameter of the head and one half the minor axis equal to the depth of the head. The maximum variation from this true ellipse shall not exceed 0.125 times the inside diameter of the head.

PARS. P-195(*l*)(2) AND U-36(*j*)(2). Revise the first section as follows:

(2) The maximum allowable diameter of any unreinforced opening in a head, except in a full-hemispherical head, shall not exceed that permitted by the rules in Par. P-268(*a*) (U-59*a*) for a shell:

(*A*) OF THE SAME OUTSIDE diameter AS THE OUTSIDE DIAMETER OF THE FLANGE OF THE HEAD;

(*B*) OF THE SAME thickness AS THE ACTUAL THICKNESS OF THE HEAD;

(*C*) OF THE SAME material AS THAT IN THE HEAD AND FOR THE SAME working pressure; BUT IN NO CASE [nor] shall [it] THE DIAMETER OF THE OPENING exceed 8 in. [in any case.]

PARS. P-197(*a*) AND U-38(*a*). Revise the second sentence to read:

In no case shall the thinning down, [at the corner radius] DUE TO PROCESS OF FORMING, of the knuckle PORTION of any dished head, CONSISTING OF A SEGMENT OF A SPHERE ENCIRCLED BY A PART OF A TORUS CONSTITUTING THE KNUCKLE PORTION (torispherical), [due to the process of forming] exceed 10 per cent of the thickness required by the formula in Par. P-195(*a*) (U-36*a*).

Add the following as the third sentence:

Other types of heads shall have a thickness after forming of not less than that required by the applicable formula.

PAR. P-229(*e*). Insert the following as the second section:

Valves and fittings otherwise complying with the requirements of the American Standard, but having butt welding ends, may be rated at the pressures state in that Standard for ring joints (See Table P-15).

PAR. P-299(*g*). Revise first sentence to read:

Screwed fittings of cast iron or malleable iron . . . . AS REFERRED TO [given] in Table A-11, etc.

PAR. P-300. Add the following:

Parts of boilers, such as superheater, waterwall, or economizer headers, that involve construction such as is covered by Par. P-112(*a*) (1) to (5), inclusive, may be fabricated by a manufacturer in possession of the pressure piping symbol stamp, and so stamped and reported on a Manufacturers' Partial Data Report Form (form number P-4) as called for in Par. P-332(*f*).

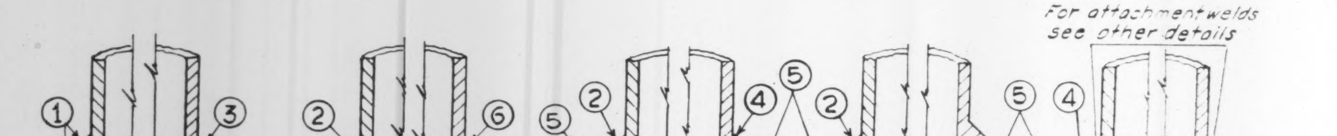
PAR. P-321. Replace first and second sentences of the second section by the following:

The steam and water connections to a water column or a water-gage glass, including all pipe, fittings, valves, and drains, shall comply with the requirements of Pars. P-9, P-23, and P-300.

PARS. A-27 AND UA-6. In the first sentence refer to A.S.T.M. Specifications E8-42 instead of E8-36.

TABLES P-6 AND U-3. In the values for

FIGS. P-36 AND U-7. Revise as follows:



For attachment welds see other details
(a)
(b)
(c)
(d)
(e)
(f)
(g)
(h)
(j)
(k)
Reinforcement may be inside, outside or both in the absence of specific requirement
(l)
(m)
(n)
(o)
(p)
(q)
(r)
(s)
Either method of attachment is satisfactory
E.H. Steel Coupling
Steel Boiler Flange
(t)
(u)
(v)
(w)
For limitations see par. U-59 b (or P 268 b)
Alternate for
t_n
t_s
t_1
t_2
$t_1 + t_2 = 1\frac{1}{4}t$ (min.)
t_1 or t_2 not less than $\frac{1}{3}t$ or $\frac{1}{4}$"
$\frac{1}{4}$" min.
$\frac{3}{8}$" min.
B = L or $\frac{1}{4}$" where L exceeds $\frac{1}{4}$"
Weld from one side
④ $t_1 = \frac{3}{4}t$ (min.)
⑤ $t_2 = \frac{1}{2}t$ (min.)
④ $t_1 = \frac{1}{4}$" (min.) if welded from both sides
$t_1 = \frac{3}{8}$" (min.) if welded from one side
⑤ $t_2 = \frac{1}{2}t$ (min.) Weld from both sides
t_n min.
④ $t_1 = \frac{3}{4}t$ min.
⑧ Weld to pad
Dimensions ① ④ & ⑤ are minimum values where t = the thinner of t_s or t_n
t_s = the required shell thickness, t_n = the required neck thickness

FIGS. U-7 AND P-36 SOME ACCEPTABLE TYPES OF FUSION-WELDED NOZZLES AND OTHER CONNECTIONS TO SHELLS OR DRUMS

(NOTE: The above arrangements are illustrative only. Any other design that meets the requirements of P-268(*g*) and (*h*) or U-59(*g*) and (*h*) will be acceptable. Weld dimensions indicated are minimum values. For reinforced openings the strength of all welds should be checked to conform with Par. U-59(*g*) and (*h*).

Muntz metal at 300 F change "5500" to "7500," and at 350 F change "2000" to "4500." Add values of 10,000 psi for temperatures listed up to and including 450 F for copper alloy condenser tube plates (A.S.T.M. B171-42T).

TABLES P-7 AND U-2. Add the following stresses for Specification S-52, grades T-17, T-21, and T-22:

Grade	Spec. no.	Min. tens. strength	—20 to 650	700	750	800	850	900
T-17	S-52	60000 (14)	12000	..	..	..	..	..
T-21,T-22	S-52	60000	12000	12000	12000	11800	11200	10000

Grade	950	1000	1050	1100	1150	1200
T-17	..	..	..	..	..	..
T-21	8250	6250	4800	3700	2700	1950

(14) Between temperatures of 650 to 1000 F, inclusive, the stresses given herein for killed carbon steel, Specification S-42, grade B, may be used until high temperature test data becomes available.

TABLE U-3. Add the following values for temperatures listed up to and including 400 F for aluminum, annealed, Specification S-38: 2240, 1680, 1440, 1280, 1120.

TABLE A-11. In the heading of this table change references to American Standards to B16d-1941 and B16c-1939; omit sizes for 14 OD and 16 OD, and the dimension for 150 lb malleable-iron screwed fittings for 8 in. nominal pipe size.

SPECIFICATIONS S-12. This specification for carbon-steel castings for valves, flanges, and fittings for high-temperature service (A.S.T.M. A95-41) will be reinstated in the Code with a note to the effect that this material is not suitable for welding. Reference thereto will be made in Pars. P-9(*a*), P-10, P-11, and P-13. Stresses similar to those for Specification S-56 will be incorporated in Tables P-7 and U-2.

A.S.T.M. Specifications B171-42T for Copper-Alloy Condenser Tube Plates will be incorporated in Section II of the Code.

A.S.T.M. Specifications A197-39 for Cupola Malleable Iron will be incorporated in Section II of the Code.

SPECIFICATION S-63 will be revised to make it identical with A.S.T.M. Specifications A233-42T.

A.S.T.M. Specifications A251-42T for Iron and Steel Gas-Welding Rods will be incorporated in Section IX of the Code.

A.S.T.M. Specifications A226-40 for Electric-Resistance Welded Steel Boiler and Superheater Tubes for High-Pressure Service will be incorporated in Section II of the Code.

PARS. U-69(*c*) AND U-70(*c*). Revise to read as follows:

(*c*) THE QUALIFICATION OF THE WELDING PROCEDURES AND THE WELDING OPERATORS SHALL COMPLY WITH THE REQUIREMENTS OF SECTION IX OF THIS CODE, EXCEPT:

(1) A welding operator who has been regularly qualified and engaged in welding Par. U-68 vessels is qualified thereby to weld Par. U-69 (U-70) vessels provided the same procedure and position are employed as those for which the operator has been qualified;

(2) AS MAY BE OTHERWISE PROVIDED.

PAR. U-71(*a*). Introduce the word "ferrous" at the beginning of this paragraph.

PAR. U-75. Revise first section to read:

U-75 *Dished Heads.* Dished heads convex to the pressure shall have a flange not less than $1^1/_2$ in. long except where the thickness is $^3/_8$ in. or under, in which case the flange need not be more than 4 times the thickness of the head. When heads are inserted into the shell, it shall be with a driving fit and welded as shown in Fig. U-15.

PAR. U-76(*d*). Set up the second sentence of the second section as a new section. Rewrite item (2) as follows:

(2) For material containing not to exceed 0.35 per cent carbon, the diameter of the equivalent holes, IN A VESSEL FOR WHICH STRESS RELIEF AS A WHOLE IS REQUIRED, shall be taken as the maximum dimension of the weld plus $^1/_2$ in., but in no case shall a weld exceed 3 in. in length;

In the title of the Rules for Containers for Gases and Liquids preceding Par. U-140 change the temperature limit to "—20 F and below."

PAR. UA-19(*f*). In the first sentence change "high-hubbed flanges to "hubbed flanges."

REVIEWS OF BOOKS

And Notes on Books Received in the Engineering Societies Library

Handbook of Applied Hydraulics

HANDBOOK OF APPLIED HYDRAULICS. Calvin Victor Davis, editor in chief. McGraw-Hill Book Company, Inc., New York, N. Y., 1942. Fabrikoid, 6 × 9 in., 1084 pp., illus., $7.50.

REVIEWED BY ARTHUR M. GREENE, JR.[1]

THIS excellent handbook of twenty-three sections dealing with hydraulics applied to power development and machinery; water supply, its treatment and distribution; sewerage and sewage; irrigation and drainage has been written by eighteen experts of whom eight are from government authorities or services, five are practicing engineers, and five are engineering teachers. From their broad experiences these authors have brought together in one volume descriptions, drawings, and discussion of principles of machinery, structures, and procedures involving hydraulics. Not only are the foregoing listed subjects treated in some of the sections but also hydraulic formulas, hydrology, regulation by reservoirs, different forms of dams, spillways, outlet works, open channels and pipes, as well as testing of models are covered in particular sections.

The text has numerous valuable extensive tables and charts giving data and requirements for problems relating to the subject as given in the following lists by sections:

Section 1, Hydraulic Formulas.

Section 2, Hydrology: Evaporation, precipitation, soil losses, river discharge, run-off, flood discharge.

Section 3, River Regulation by Reservoirs: Flow curves, silt table.

Section 4, Gravity Dams: Structural analysis.

Section 5, Arch Dams: Maximum stresses, material constants, formulas for load constants, data from existing arch dams.

Section 6, Buttress Dams: Diagrams of dams, flow net diagrams, creep ratios.

Section 7, Earth Dams: Permeability curve.

Section 8, Rock-Fill Dams: Sliding factors, creep ratios and factors, crest settlement, important rock-fill dams.

Section 9, Spillways and Stream Bed Protection Works: Nappe co-ordinates.

Section 10, Spillway Crest Gates: Gate details.

Section 11, High-Pressure Outlet Works: Gate details.

Section 12, Canals, Flumes, Covered Conduits, Tunnels, and Pipe Lines: Permissible canal velocities, properties of partially filled conduits, thrust and moment coefficients of pipes.

Section 13, Hydroelectric Plants: Yearly electricity production, classification of turbines built from 1928 to 1936, federal hydroelectric plants, undeveloped water power, principal power streams of the United States, turbine and plant efficiencies of modern plants, power distribution from Boulder plant, from Safe Harbor plant, co-ordinated hydro plants on various single river systems, cost of power, economic height of power dam, economic size of canal, representative plants, storage determination, negative draft-tube pressure.

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Section 14, Hydraulic Machinery: Turbine details, turbine laws, specific-speed charts for turbines and pumps, variation of efficiency of turbines, cavitation coefficients and limitations, limitations of specific speeds, height of barometric column with temperature and elevation, scale effect, combined operation of several turbine units, pump details.

Section 15, Water Supply: Water consumption in buildings and for fires, population forecast, ground-water flow.

Section 16, Water Distribution: Flow requirements for plumbing fixtures, hydrant areas, design of distributing system network, corrosion resistance of metals, variation of flow with age.

Section 17, Water Treatment: Substances in natural waters, ionization, flow diagrams for treatment, settling velocities, analysis of raw water.

Section 18, Sewerage: Population-increase provisions, population ratios, population forecasts, population densities, capacity factors, sewage flow in various cities, water consumption and sewage data, probable variation of flow, industrial and commercial flow, sewer lengths per capita, storm sewer data, runoff coefficients, currents for solid movement, hydraulic elements of conduits, design with chart and tables, intercepting sewer data, details, pumping data, pumping stations.

Section 18, Sewage Treatment, Hydraulics: Details, flow diagrams for new plants, hydraulic losses, and head requirements.

Section 19, Irrigation: Snowfall, rainfall, runoff, return flow, basin requirements, average use of water, crop requirements, canal losses and wastes, consumptive use, results of irrigation.

Section 20, Irrigation.

Section 21, Irrigation Structures: Data from some canals, structural details.

Section 22, Drainage: Curves and charts for drainage design.

Section 23, Hydraulic Models: Half tones of models.

Many of the sections contain numerous references to engineering literature from which the bases for statements, treatments, or formulas may be studied if more detail is needed by the reader. Many of these are from articles not available to the man located some distance from a large library. The references, however, may be used to secure the publication from publishers or government agencies in case of need for this further study.

Although there has been most excellent monumental work done on the plants, constructed at governmental expense by the engineers of the various bureaus and agencies, which are described in the text, it is regretted that there are not more drawings and descriptions of devices at plants built by private enterprise. For instance there is no showing of the Johnson valve or such butterfly valves as those at the Conowingo Power Plant. There is no diagram of the White hydrocone although this is mentioned and the one drawing showing the Moody spreading draft tube is small and nothing is said of the action of these two tubes. It seems strange to read on page 434 in a handbook for the aid of all engineers that there was a substantial saving over the cost of commercial types of butterfly valves available by the design and government specifications of the butterfly valves for the Boulder Dam penstocks. It might be asked if the builders of hydraulic machinery had a chance to submit bids on a special valve designed by them for this particular installation.

However, this lack of drawings from commercial plants is unfortunate; those shown are most excellent and undoubtedly represent most recent structures with which the authors have been directly connected. Many of the sections contain illustrations of methods used in the hydraulic design of special projects and make clear the procedure in applying the theory discussed.

A handbook should contain not only the excellent matter presented in this book but it should also have other formulas and applications of theory needed by the man who uses the book in its particular field when he is away from the numerous books of his library. Then he turns to the handbook for confirmation of memory, for formulas or theory long forgotten, or for the discussion of a new topic. It is omissions of important subjects and the apparent governmental bias of the text which are the shortcomings of this book to the reviewer.

Although the book is intended for use by those who have a knowledge of elementary hydraulics, some of the subjects omitted in the incomplete first section on hydraulic formulas are the following: dependence of friction factor for pipe upon Reynolds number, water hammer, variation of viscosity and weight of water with temperature, critical velocity of flow, Giesecke's results on friction loss in cast and welded fittings, coefficients and formulas for triangular notches and Cippoletti wiers. On page 600 it is stated that this missing water hammer is given in section 1 and another use of the most important nondimensional Reynolds number is mentioned on page 1032 in the section on hydraulic models. The viscosity of water is given on page 792 under water treatment although the reviewer has not found it in the index under water or viscosity.

The methods of stream gaging and the instruments used for such as well as the Allen salt method and the Gibson method of measuring water flow are not illustrated and discussed. The methods and requirements in the design of surge tanks is not given in outline although a reference is given to only one of Johnson's papers on this subject. The surge tank was not found on reference to the index.

Probability paper is used to show the probable variation of flow in sewers with time but the use of this diagram for the plotting of stream flow is not indicated in the earlier sections of the text in which it may be used effectively.

The book is well printed and excellently built as is customary in books of the McGraw-Hill Book Company. The diagrams, drawings, and half tones are clear and usable except for a very few in which reduction has been carried too far in the endeavor to print them on one page.

Books Received in Library

✓ APPLIED KINEMATICS for Students and Mechanical Designers. By J. H. Billings. Second edition. D. Van Nostrand Co., Inc., New York, N. Y., 1943. Cloth, 6 × 9½ in., 320 pp., illus., diagrams, charts, tables, $3.25. The principles governing motion and the design of machine elements are presented. As far as possible, simple graphical methods are used. The illustrative material and problems are related to engineering practice. Special attention is given to acceleration.

A.S.T.M. STANDARDS ON PAINT, VARNISH, LACQUER, AND RELATED PRODUCTS. Prepared by Committee D-1 on Paint, Varnish, Lacquer, and Related Products; Specifications, Methods of Testing, Definitions of Terms. December, 1942. American Society for Testing Materials, Philadelphia, Pa., 1943. Paper, 6 × 9 in., 408 pp., illus., diagrams, charts, tables, $2.25. This compilation of standards contains in their latest form more than 120 specifications, tests, and definitions relating to paint, varnish, lacquer, and their constituents. A number of specifications and tests are new.

✓ ELEMENTS OF SUPERVISION. By W. R. Spriegel and E. Schulz. John Wiley & Sons, Inc., New York, N. Y.; Chapman & Hall, London, England, 1942. Paper, 9½ × 6 in., 273 pp., diagrams, tables, $2.25. Present rapid industrial expansion has created a shortage of trained supervisors and a need for texts which describe the functions of supervisors and methods for training them. The present book meets this need by giving an account of the duties of the position, the problems involved and the ways of meeting them, and of practical methods of training.

✓ ENGINEERING MECHANICS. By G. N. Cox. D. Van Nostrand Co., Inc., New York, N. Y., 1943. Cloth, 9½ × 6 in., 301 pp., diagrams, charts, tables, $3. In preparing this textbook, the author has endeavored to co-ordinate the desires of our engineering teachers as expressed in the surveys conducted by the Society for the Promotion of Engineering Education. The book is intended for undergraduate students majoring in engineering and calls for a working knowledge of physics and the calculus.

Foremanship and Safety. By C. M. MacMillan. John Wiley & Sons, Inc., New York, N. Y.; Chapman & Hall, London, England, 1943. Stiff Paper, 6 × 9 in., 101 pp., illus., tables, \$1. This little book explains in clear simple language the safety problems that confront the foreman and the way they should be handled. All important phases of everyday industrial accident prevention are discussed.

Hypergeometric and Legendre Functions With Applications to Integral Equations of Potential Theory. By C. Snow. U. S. Bureau of Standards, Washington, D. C., 1942. Paper, 11 × $9^{1}/_{2}$ in., 319 pp., photo-offset of longhand, diagrams, \$2. This work has been compiled for workers in applied mathematics and is intermediate between tables of the numerical values of these functions and a treatise on their pure theory. The linear and quadratic transformations and analytic continuations of the ordinary hypergeometric function are derived and written out at length with special space devoted to the associated Legendre functions, and, to a smaller extent, Heun's generalization of the hypergeometric function. Many applications to potential theory are developed.

Machine Design. By P. H. Hyland and V. B. Kommers. Third edition. McGraw-Hill Book Co., Inc., New York, N. Y., and London, England, 1943. Cloth, $9^{1}/_{2}$ × 6 in., 562 pp., illus., diagrams, charts, tables, \$4.50. This is a carefully illustrated college textbook covering the elements of machine design and containing numerous problems. This edition has been revised throughout, new material replacing old wherever necessary.

Mechanism. By I. H. Prageman. International Textbook Co., Scranton, Pa., 1943. Fabrikoid, $8^{1}/_{2}$ × $5^{1}/_{2}$ in., 296 pp., diagrams, charts, tables, \$3. An elementary text for use by sophomore or junior students of engineering. The motions, velocities, and accelerations of various machine parts are described, as are static forces that may be transmitted in some of the simpler machines, and inertia forces acting on machine parts.

National Conference on Planning, Proceedings of the Conference Held at Indianapolis, Indiana, May 25–27, 1942. American Society of Planning Officials, 1313 East 60th St., Chicago, Ill., 1942. Cloth, $9^{1}/_{2}$ × 6 in., 228 pp., diagrams, charts, tables, \$2.50. This book presents addresses and discussions at the Conference, all of which deal with real problems of the present day. Postwar planning, the problem of converting war industries to peace uses, the manpower crisis, war housing and city rebuilding after victory, state and municipal planning, are discussed by experienced men.

Noxious Gases and the Principles of Respiration Influencing Their Action. (American Chemical Society Monograph Series No. 35.) By Y. Henderson and H. W. Haggard. Second revised edition. Reinhold Publishing Corp., New York, N. Y., 1943. Cloth, $9^{1}/_{2}$ × 6 in., 294 pp., diagrams, charts, tables, \$3.50. In this work, two experienced physiologists review the poisonous gases and vapors and discuss their efforts and the methods of treatment. The book is designed for chemists, engineers, and others engaged in industry and covers all the noxious gases that occur in industry. The functions of respiration are considered, as well as methods of protection against poisoning.

Patents and Industrial Progress. By G. E. Folk with a foreword by R. L. Lund. Harper & Brothers, New York, N. Y., and London, England, 1942. Cloth, $8^{1}/_{2}$ × $5^{1}/_{2}$ in., 393 pp., diagrams, charts, maps, tables, \$3. In 1938 the Temporary National Economic Committee was created by Congress to study the concentration of economic power and among other matters, "the amendment of the patent laws to prevent their uses to suppress inventions, and to create industrial monopolies." The present book is an evaluation of the testimony taken on the patent system, by an eminent patent attorney, with comments on the wisdom of the legislation recommended.

Practical Marine Diesel Engineering. By L. R. Ford. Fourth edition. Simmons-Boardman Publishing Corp., New York, N. Y., 1943. Cloth, $9^{1}/_{2}$ × 6 in., 642 pp., illus., diagrams, charts, tables, \$6. The construction, operation, and maintenance of marine Diesel engines are explained thoroughly, from the point of view of the operating engineer. The work is limited to the makes of engines that are being most used in the types of vessels now being built, especially those developed by the U. S. Maritime Commission. Other features are discussions of Diesel tugs, of deck and electrical machinery, and of shipyard engine repairs. A chapter on license requirements is included.

Pre-Service Course in Automotive Mechanics. By J. V. Frost. John Wiley & Sons, Inc., New York, N. Y.; Chapman & Hall, London, England, 1943. Cloth, 9 × $5^{1}/_{2}$ in., 545 pp., illus., diagrams, charts, tables, \$2.50. The subject is treated principally from the theoretical point of view in this well-planned text, which is based on the outline for pre-induction training prepared by the War Department. The course is adapted to high-school students. The construction and operating principles of all motor vehicles are covered.

Pre-Service Course in Electricity. By W. C. Shea. John Wiley & Sons, Inc., New York, N. Y., Chapman & Hall, London, England, 1943. Cloth, 9 × $5^{1}/_{2}$ in., 276 pp., illus., diagrams, charts, tables, \$2. This book follows the outline of a basic course for pre-induction training which has been prepared by the War Department and the Office of Education. The book covers the fundamentals of electricity, including information prerequisite to work in radio, aviation, motor mechanics, and other special subjects of military importance.

Pre-Service Course in Shop Practice. By W. J. Kennedy. John Wiley & Sons, Inc., New York, N. Y.; Chapman & Hall, Ltd., London, England, 1943. Cloth, 9 × $5^{1}/_{2}$ in., 337 pp., illus., diagrams, charts, tables, \$2. This book is based upon the requirements of the U. S. Army for pre-induction training to be given to high-school seniors. Starting with accounts of hand and machine tools, the book proceeds to treat in more detail the tools and shop processes most used by the army. Cutting, planing, finishing, etc., are explained. A chapter is included on wiring and one on ropes and splices. Blocks and rigging are also explained.

Principles of Metallographic Laboratory Practice. By G. L. Kehl. Second edition. McGraw-Hill Book Co., New York N. Y., and London, England, 1943. Cloth, $9^{1}/_{2}$ × 6 in., 453 pp., illus., diagrams, charts, tables, \$4. This textbook presents the principles of physical metallurgy which underlie effective laboratory practice and is intended to bridge the gap between theoretical physical metallurgy and its practical application in the laboratory. The new edition follows the plan of the previous one but has been revised to include recent advances.

Library Services

Engineering Societies Library books may be borrowed by mail by A.S.M.E. members for a small handling charge. The Library also prepares bibliographies, maintains search and photostat services, and can provide microfilm copies of any item in its collection. Address inquiries to Harrison W. Craver, Director, Engineering Societies Library, 29 West 39th St., New York, N. Y.

Questions and Answers for Marine Engineers, Book V—Powering, Fuel Economy, Propulsion, Propellers and Shafting. Compiled by H. C. Dinger. *Marine Engineering and Shipping Review*, Simmons-Boardman Publishing Co., New York, N. Y., 1943. Paper, 8 × 5 in., 97 pp., diagrams, charts, tables, \$1. These questions and answers have been selected from those published during the last ten years in Marine Engineering and Shipping Review. They give information on the powering of ships, special methods of propulsion and control, on fuel consumption, tonnage, hull characteristics, propellers, and shafting. The booklet is a handy reference for marine engineers and for those preparing for examinations.

Table of Arc Tan X, prepared by the Federal Works Agency, Work Projects Administration for the City of New York, as a Report of Official Project No. 165-2-97-22, Mathematical Tables Project. A. N. Lowan, Technical Directory; conducted under the sponsorship and for sale by the National Bureau of Standards, Washington, D. C., 1942. Cloth, 11 × 8 in., 169 pp., tables, \$2. This table of the inverse tangent is claimed to be the most comprehensive yet published. The angle is given in radians, and the function is calculated to twelve decimals, calculated over the range of X from 0 to 10,000.

Theory of Emulsions and Their Technical Treatment. By W. Clayton. Fourth edition. Blakiston Co., Philadelphia, Pa., 1943. Cloth, 10 × 6 in., 492 pp., illus., diagrams, charts, tables, \$10. This book provides a thorough study of emulsions with emphasis on their practical treatment and industrial application. The previous edition has been out of print for some years, during which much has been done on the general theory of emulsions, which has been used in this revision. Old matter has been deleted and the literature thoroughly covered. Copious references are provided to papers and patents. Theories of emulsions, properties of emulsions, the preparation of emulsions, and de-emulsification are discussed.

Theory of the Photographic Process. By C. E. K. Mees. The Macmillan Co., New York, N. Y., 1943. Cloth, 6 × $9^{1}/_{2}$ in., 1124 pp., illus., diagrams, charts, tables, \$12. During the last fifty years a fund of knowledge of the photographic process has been built up, which is scattered through many journals. The present volume is a general handbook of the subject, which provides a guide to the literature and a summary of its conclusions. The author has had the assistance of many specialists. There are bibliographies with each chapter.

Transients in Linear Systems, Studied by the Laplace Transformation. Vol. 1, Lumped-Constant Systems. By M. F. Gardner and J. L. Barnes. John Wiley & Sons, Inc., New York, N. Y.; Chapman & Hall, London, England, 1942. Cloth, $9^{1}/_{2}$ × 6 in., 389 pp., diagrams, charts, tables, \$5. This exposition of the subject is intended primarily for graduate students of electrical and mechanical engineering, but can also be used for graduate work in mathematical physics and applied mathematics. Volume 1 deals with lumped-constant systems. The book contains an extensive bibliography.

A.S.M.E. NEWS

And Notes on Other Engineering Activities

Program at 1943 A.S.M.E. Semi-Annual Meeting, June 14–17, to Be Tied to Aviation Problems

Hotel Biltmore, Los Angeles, Calif., to Be Headquarters

AVIATION will steal the show at the 1943 Semi-Annual Meeting of The American Society of Mechanical Engineers, scheduled for June 14–17, at the Hotel Biltmore, Los Angeles, California.

Early this year, Dr. John A. Younger, secretary of the A.S.M.E. Aviation Division, spent several weeks on the Pacific Coast laying the groundwork for the most extensive Semi-Annual Meeting program the A.S.M.E. has sponsored in many years. In the universities, the airplane-manufacturing plants, the petroleum industries, and among members of the Executive Committee of the Los Angeles Section Dr. Younger found tremendous enthusiasm for the role that the Society can play in contributing to the quick success of the war program.

Whatever the ultimate product of manufacture, mechanical engineering plays many vital roles in production. Airplane manufacture presents an endless series of such problems, from laboratory to flight test. Petroleum engineering leans heavily on the design of machinery, pressure vessels, and heat-transfer equipment, all subjects of prime importance in the engineering field. Wherever manufacturing is carried on the problems of management are paramount; and under wartime conditions the training of workers and the substitution of women for men in shops and engineering offices are subjects which mechanical engineers have drawn into their special field of interest.

Technical Program Longer Than Usual

It is indicative of the rapid advance of engineering and of the tremendous importance it has in the prosecution of the war that the technical program of the Los Angeles Semi-Annual Meeting is likely to be as extensive as an Annual Meeting program of a few years ago.

Drawing upon the richly abundant talent which the Pacific Coast aviation plants afford and upon leaders in mechanical engineering from coast to coast, the authors and discussers already lined up for the meeting bear testimony to the high caliber of engineering information that can be absorbed by persons attending the meeting. Much of the program is of a nature that will make publication difficult or impossible and hence full benefit can be had only by attending in person. With the program as arranged, members of the Society will have no difficulty in convincing themselves that they must take time out from their busy careers to regenerate their minds, get new ideas, and meet the men who are carrying the load of airplane design and construction on the Pacific Coast.

Los Angeles Chamber of Commerce

DOUGLAS MAC ARTHUR PARK LOOKING EAST, LOS ANGELES, CALIFORNIA

Registration Fee for Non-Members at 1943 Semi-Annual Spring Meeting

There will be a registration fee of $2 for nonmembers attending the 1943 A.S.M.E. Semi-Annual Meeting at Los Angeles, Calif., June 14–17, 1943. For nonmembers wishing to attend just one session the fee will be $1. This is in accordance with the ruling of the Standing Committee on Meetings and Program.

Members wishing to bring nonmember guests may avoid this fee by writing to the Secretary of the Society before June 4, 1943, asking for a guest-attendance card for the Semi-Annual Meeting. The card, upon presentation by a guest, will be accepted in lieu of the registration fee. Guests are limited to *two per member*.

Aviation the Keynote

Although the bulk of the Los Angeles program is based on the Aviation Division, joint sessions with other divisions afford the usual diversification of interest. At present there are three sessions to be held jointly with the Process Industries Division, two with the Applied

Mechanics Division, two with the Committee on Education and Training for the Industries, one with the Management Division, two with the Hydraulics Division, two with the Heat Transfer Division, two with the Rubber and Plastics Division, and one with the Power Division. In addition to these sessions there will be others sponsored by the Petroleum and Railroad Divisions.

W. F. Durand to Preside at Opening Luncheon

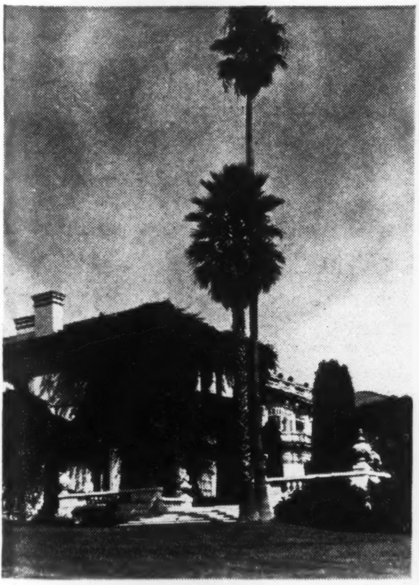
Present plans call for a luncheon on the opening day of the meeting at which W. F. Durand, past-president and honorary member, A.S.M.E., and member of the National Advisory Committee for Aeronautics, will preside. The subject of the luncheon addresses will be "Combat to Cargo Airplanes," and the speakers will represent air commerce, manufacture, and government aviation.

The two sessions on Women in Industry and Engineering will feature the training and work of women at Vultee, by I. J. Hanson, supervisor of training, Vultee Aircraft Corporation, Downey, Calif.; engineering training for women at Wright Aeronautical Corporation, by C. W. Cole, Wright Aeronautical Corporation, Paterson, N. J.; and training of women engineers for the aviation industry, by E. D. Howe, supervisor, E.S.M.W.T., University of California, Los Angeles, Calif.

R. F. Gagg, chairman, A.S.M.E. Aviation Division, and assistant general manager, Wright Aeronautical Corporation, Paterson, N. J., will present a paper on the management problems at the Wright plant.

Hydraulics in Airplane Systems

Three papers on hydraulics are being lined up for Los Angeles: A Symposium on Airplane Hydraulic Systems, by Howard Field, North American Aviation Corp., Englewood, Calif.; Hydraulic Versus Electric Operation of Aircraft Units, by Richard Hayman, Lockheed Aircraft Corp., Burbank, Calif.; and The Modern Hydraulic Reservoir; How it Provides Micron Filtration and Pump Supercharging, by W. W. Thayer, Douglas Aircraft Company, Santa Monica, Calif.



Los Angeles Chamber of Commerce

HUNTINGTON LIBRARY AND ART GALLERY

(Where priceless paintings, tapestries, sculptures, and manuscripts may be studied.)

Heat Transfer Division Participates

In the field of heat transfer, F. Ryder, R. R. Martinelli, and A. E. Harrison, University of California, Berkeley, Calif., will present a paper on The Hot-Wire Anemometer and Its Application to the Measurement of Intake-Manifold Velocities. A. L. London, Stanford University, is scheduled for a paper on the Design and Calibration of a Thermal Anemometer; and M. E. Moore, Douglas Aircraft Company, one on automatic temperature-recording control system. Other papers sponsored jointly by the Aviation and Heat Transfer Divisions will include Test and Predicted Behaviors of Engine Oil Coolers, by A. L. London, Stanford University; and Aircraft Heating and Ventilating Systems, by W. W. Reaser, Douglas Aircraft Company, Santa Monica, Calif.

Superchargers to Be Discussed

Two papers have been arranged for in the field of superchargers, one by R. G. Standerwick and the other by Sanford A. Moss, both of the General Electric Company.

Prof. A. Klemin, of New York University, will be one of the speakers on the subject of cargo-plane design.

Official Notice

A.S.M.E. Business Meeting

The Semi-Annual Business Meeting of the members of The American Society of Mechanical Engineers will be held Monday afternoon, June 14, 1943, at 2:00 p.m. at the Hotel Blackhawk, Los Angeles, Calif., as a part of the Semi-Annual Meeting of the Society.

(*Signed*) C. E. Davies
Secretary

Salvaging of aircraft structures will be discussed by R. L. Schleicher, chief of structures, North American Aviation Corp., Englewood, Calif.; and the role of production research in modern industry, by Mabel M. Rockwell, chief of production research, Lockheed Aircraft Corporation, Burbank, Calif.

Production Engineering Featured

In the field of production the tentative program includes a panel discussion on production headed by T. A. Watson, director, E.S.M.W.T. Training, University of Calif., Los Angeles, Calif., with panel members representing Douglas, Vega, Lockheed, and Vultee.

At another production-engineering session, W. Schroeder, assistant chief of research, Lockheed Aircraft Corp., Burbank, Calif., will speak on the Mechanics of Sheet-Metal Bending, and P. L. Smith, of Douglas Aircraft Company, Santa Monica, Calif., on Metal Forming Technique.

Plastics and Aircraft

Three papers are also scheduled in the field of plastics. The first will deal with Factors Limiting the Application of Plastics in Aircraft, by Frank Krieger of the Douglas Aircraft Corporation. The second will be presented by C. W. Armstrong, of Lockheed Aircraft Corporation, on Physical Properties of a Structural Plastic Material, and the third by John Delmonte, of Plastics Industries Technical Institute, on Woods, Cloth, and Wood-Paper Laminates.

Los Angeles Chamber of Commerce

A CITY PARK IN THE HEART OF DOWNTOWN LOS ANGELES

Timoshenko and von Kármán on Program

Dr. S. Timoshenko, Stanford University, Calif., and Dr. Th. von Kármán, California Institute of Technology, Pasadena, Calif., are scheduled to appear at the same session on the joint Aviation–Applied Mechanics program. Dr. Timoshenko's subject is, Problems of Elastic Instability in Aircraft Structures. Dr. von Kármán's paper will deal with Nonlinear Instability Problems in Aircraft Structures.

At the second Applied Mechanics session H. L. Langhaar, structures engineer, Consolidated Aircraft Corporation, San Diego, Calif., is preparing to discuss a theoretical and experimental investigation of thin-webbed plate girder beams, and M. V. Barton, department of aeronautical engineering, University of Texas, with J. N. Goodier, Cornell University, are planning a paper on the effect of webbed distortion on the torsion of I-beams.

Program Not Yet Complete

Although the program for Los Angeles is still in a very tentative form, the foregoing glimpses of what has been suggested to date will give an idea of the extent and variety of subject matter to be treated. Complete announcements will be made in the June issue.

J. Calvin Brown Heads Local Committee

In charge of the local program at Los Angeles is J. Calvin Brown, chairman of the A.S.M.E. Southern California Section. J. S. Gallagher is vice-chairman of the Section and R. G. Roshong is secretary-treasurer. The personnel of the Semi-Annual Meeting committee has not yet been announced.

President Coes to Speak at Banquet

The Council of the Society will meet in connection with the Los Angeles meeting and the Semi-Annual Business Meeting will be one of the features of the program. H. V. Coes, president of the Society, has promised to be present and it is expected that he will speak at the banquet to be held during the week.

Actions of A.S.M.E. Executive Committee

At Meeting in Society Headquarters on March 26

A MEETING of the Executive Committee of the Council of The American Society of Mechanical Engineers was held at the Society headquarters, New York, N. Y., on March 26, with Harold V. Coes, president of the Society, in the chair. In addition to Mr. Coes there were present: Clarke Freeman, vice-chairman, A. R. Stevenson, Jr., of the Committee; G. L. Knight (Finance), W. A. Carter (Professional Divisions), A. R. Mumford (Local Sections), H. A. Lardner (A.S.M.E. representative on U.E.T.); C. E. Davies, secretary; Ernest Hartford, executive assistant secretary; and during the afternoon session C. H. Barker, Jr., secretary, and J. A. Jackson, member, Executive Committee of the Materials Handling Division.

The following actions were of general interest.

National Conference on Engineering Positions

Decision to disband the National Conference on Engineering Positions, a joint activity initiated in 1939, was reported by the secretary.

1942 Group Delegates Recommendations

Statements of the Council's action on the recommendations of the 1942 Group Delegates Conference were adopted. Mimeographed copies are available.

Management

The President was authorized to appoint a special committee of five members to suggest a program to be followed by the Society which would result in a broader program of interest to top management, the interest of top management in the work of the Society, and a program of vitalizing the interest of individual sections in management discussions.

Association of Mexican Engineers and Architects

The secretary reported that the president had sent the greetings of the Society to the Association of Mexican Engineers and Architects on the occasion of the Seventy-Fifth Anniversary of that association.

Deaths Reported

The death, on March 6, of Chas. T. Main, past-president and honorary member, A.S.M.E., was noted with regret. It was reported that Clarke Freeman had acted as one of the honorary pall-bearers at the funeral and that, in addition, the Society had been represented by I. E. Moultrop, D. C. Jackson, and Kerr Atkinson, honorary vice-presidents.

The deaths, on February 23, of W. J. Sando, former member of the Council, and on March 20, of A. L. Kimball, former chairman, Committee on Meetings and Program, were noted.

Office of Production Research and Development

In February the Executive Committee authorized the establishment of a Manufacturing Engineering Committee and a contract with the War Production Board whereby the services of this committee would be made available to the Office of Production Research and Development. The secretary reported that the contract would be signed shortly (it was signed later in the month) and an administrative secretary would be appointed to serve the committee and work with the Office of Production Research and Development. Herbert B. Lewis, of Providence, R. I., member A.S.M.E., has been appointed executive secretary of the committee. Mr. Lewis will make his headquarters in New York City, at 40 West 40th St.

Appointments

The following appointments were reported for the record:

Committee on Industrial Conservation; A. M. Perrin, chairman, R. D. Bullard, Graham Granger, R. A. Wheeler.

Committee on Dues-Exempt-Members' Contributions: N. T. McKee, S. M. Marshall, C. R. Place.

Committee on Engineers' Civic Responsibilities: M. H. Fies, H. H. Snelling.

Committee on Employment Clearing House: A. H. Meyer, A. R. Mumford, J. H. Walker.

Committee on Standardization of Steam Turbines: K. M. Irwin, chairman, R. C. Allen, C. B. Campbell, A. G. Christie, G. A. Gaffert, E. H. Krieg, A. L. Penniman, Jr., W. F. Ryan, G. B. Warren.

Standardization Sectional Committee on Transmission Chains and Sprockets, B29: J. M. Bryant.

Hoover Medal Board of Award: S. F. Voorhees (reappointed, 6 years).

Quarterly of Applied Mathematics: J. M. Lessells, liaison officer.

Regional Technical Advisory Committee, O.C.D.: John A. Willard, representative.

E.C.P.D. Issues 1942 Annual Report

Chairman R. E. Doherty Relates Council's Functions to Present World Conditions

INTERESTING and useful reference material on what engineers are doing in selecting and training new personnel for the profession and in elevating the status of engineers in general is contained in the tenth annual report of the Engineers' Council for Professional Development. This Council is a joint agency of the professional societies of civil, mechanical, electrical, and mining and metallurgical engineers (known as the four Founder Societies), and of the chemical engineers, the engineering educators, the state licensing boards, and The Engineering Institute of Canada. The Council recently held its tenth annual meeting in New York City and the principal reports presented at that meeting are here assembled.

Included in the report is a list of engineering curricula approved by E.C.P.D. as of October 18, 1942. Note that the curricula so accredited are those functioning before the recently announced Army and Navy college-training programs became operative. A total of 551 curricula, at 131 institutions, are currently on the approved list. In addition, several other curricula such as aeronautical and industrial engineering are listed as options of the regular courses in some of the older curricula.

In his report, Robert E. Doherty, E.C.P.D. chairman and president of Carnegie Institute of Technology, reviewed activities of the year, relating the Council's functions to present world conditions, and referred to the work of the several committees. Especially he referred to the E.C.P.D. conference in September to discuss the problems of engineering manpower. At this conference were representatives of several government agencies who are advisory to the War Manpower Commission regarding the reserves of professional and scientific men. Also present were representatives of a number of war industries employing large numbers of engineers. As a result of this conference, a resolution was forwarded to the War Manpower Commission urging a more efficient use of available engineers and suggesting means for increasing their number.

The Committee on Student Selection and Guidance, R. L. Sackett, chairman, reported continuing assistance in the guidance of high-school students to a better knowledge of the engineering field and, particularly, summarized the findings of its study of tests and aptitudes of both arts and engineering students, as carried out in representative universities and high schools during the previous year.

Besides indicating progress in its usual activities, the Committee on Professional Training, Everett S. Lee, chairman, emphasized a new project—a manual for junior engineers—the preparation of which is now being undertaken. The Committee on Professional Recognition, Charles F. Scott, chairman, reported activity in its program of stressing the professional phases of the engineer's life. To this end, over 10,000 copies of an address by President W. E. Wickenden, of the Case School of Applied Science, were sold, and the committee was also instrumental in its reprinting by several engineering-society journals.

Certain "Canons of Engineering Ethics" were proposed by the Committee on Principles of Engineering Ethics, D. C. Jackson, chairman, which are printed in the E.C.P.D. report. This attempt to formulate ethical standards for engineers in a written code follows similar codification of principles by some other professional groups. These canons have been referred to the boards of the constituent organizations for suggestions or acceptance.

Reports by representatives of the eight constituent societies included in E.C.P.D. are printed in the report, as is also an account of the Council's annual dinner. The retirement of R. L. Sackett, dean emeritus of engineering, The Pennsylvania State College, from the chairmanship of the Committee on Student Selection and Guidance after ten years was noted; the dinner report contained the tribute to Dean Sackett.

President's Page

Engineering Education a War Necessity

EVERYONE knows of the distinguished service which science and its engineering applications have given and are giving to provide new instruments for and better protection of our armed forces. Without a continuous influx of new scientists and engineers our knowledge and our skill to make best use of it will cease to develop adequately. The "seed corn" must be saved if we are to have future harvests. What steps are being taken to provide this seed under war conditions?

Army and Navy Training Programs

The Navy Specialized Training Program, adopted after careful consideration, provides that certain student Navy reserves will continue in approved engineering colleges until July 1, 1943, and those of satisfactory standing may be authorized to continue until July 1, 1945. The basic engineering courses, so far as they have been announced by the Navy Department, contain the essentials of standard engineering education. The program includes eight semesters of sixteen weeks each.

The Army Specialized Training Program contains instruction in the basic subjects on the college level but does not cover the extent of instruction required in the normal degree program in engineering. It consists of six to seven terms of twelve weeks each and students are now being sent to selected colleges for various periods.

Engineers Needed in Army and Navy

Technical warfare requires highly trained specialists and technicians but it also demands a continuing flow of young thoroughly educated engineers. Although the need may exist for several times as many technicians and skilled workmen as engineers, it would be a shortsighted policy not to provide for both groups in proper proportion.

This is not proving to be a short war in which the future can be left to take care of itself. Plans should provide for all needed types of training in skills and education in essentials.

These students are all prospective officer material. A knowledge of the English language is necessary for efficient ordering of troop and supply movements, and instruction is being provided in both Army and Navy programs.

Industry Must Have Engineers for War Production

If the Army and Navy are to receive the best instruments and apparatus that can be devised and developed, then a steady stream of young engineers is also needed for the war industries. Goods must be delivered on time, transported without delay, and kept in repair. Without engineers to plan, to improve, to adapt to production methods, and then to produce, the military effort would quickly bog down and fail to be successful.

Engineers Needed in Management of War Plants

Engineers in management function as planners, personnel officers, production engineers, general managers, shop superintendents, plant engineers, works managers, and top executives. They have the opportunity of co-operating with labor to improve human relations and to step up production by means of new methods and machines and plant layouts which permit longer hours with no increase in fatigue. Maximum integrated production depends on intelligent management of industry.

No Instruction Without Leaders

Under modern conditions, few engineers are capable of self-education.

Teachers are necessary for instruction in fundamentals that are learned with difficulty on the job. Many teachers have already joined the armed forces or research organizations. Good teachers are always hard to obtain and now that the demand is so much greater than the supply, engineering faculties must carry considerably more than the normal number of hours per week of instruction. Without good teachers, the Navy, Army, and industrial programs of engineering education will fall far short of the nation's needs.

A few young engineers are also needed to assist in laboratory and drafting-room instruction. They cannot be conjured up by magic but must be educated.

Keep Engineers on the Job

Engineers can do their part in winning the war, whether in the armed services, the industries, or the engineering colleges, only if they are kept at tasks for which they are trained and their number is continuously augmented by properly educated young men.

(*Signed*) HAROLD V. COES, *President, A.S.M.E.*

Among the Local Sections

Salt Lake City Holds Aviation Meeting

Airplane Will Make Pigmy Out of Automobile Industry

PROF. John E. Younger, head of the department of mechanical engineering at the University of Maryland and the recipient of the "Spirit of St. Louis" medal in 1941 for aeronautical research, addressed the Utah Section of the A.S.M.E. in Salt Lake City, Utah, on March 5. His lecture was timely. He stated that developments in the aviation industry will surpass the imagination of the average citizen and that wartime inventions and developments now being made will be used in commercial planes after the war. He depicted revolutionary changes in world travel, which will see air transportation "shrinking distances unbelievably." This lecture was accompanied by slides on technical construction details. Some of the striking forecasts Professor Younger made are as follows: (1) Huge transport lines will be connecting all continents of the world; (2) Rates for airplane travel will be as cheap, perhaps cheaper, than railroad and steamship fares; (3) The gigantic airplane industry will make a pigmy out of the vast automobile industry; (4) Individual planes will be owned by thousands of persons; (5) Mass production will bring the price of airplanes down to level making them purchasable by the working class; (6) Airplane travel will be even safer than at present and there will be less risk than there is now riding in an automobile.

Akron-Canton Features Transportation

The Akron-Canton Section of the A.S.M.E. heard an interesting talk on February 18, augmented by charts and slides, on "Projecting Today's Arc Welding Into Tomorrow's Methods of Travel" by John R. Morrill. Special reference was made to new designs and development for aircraft construction.

Prof. P. B. Eaton of Anthracite-Lehigh Valley to Present Greetings to China

At a meeting of the Anthracite-Lehigh Valley Section on January 22, Prof. P. B. Eaton was made an honorary chairman in recognition of his coming trip to China. He will bear with him engrossed greetings to the Chinese Engineering Societies from the A.S.M.E. The secretary of the Section was requested to write a letter to the Chungking Section of the Chinese Engineering Institute expressing its best wishes and greetings. A splendid dinner followed the session and a farewell gift was presented to Professor Eaton. The speaker of the evening was H. C. Guhl, supervisor of development of the micarta works, Westinghouse Electric and Manufacturing Company, who spoke on "Laminated Plastics." An excellent film was shown on "Lucite," presented through the courtesy of E. I. du Pont de Nemours and Company.

Captain Nichoson Addresses Baltimore Section

At a well-attended dinner meeting of the Baltimore Section of the A.S.M.E. on March 29, Capt. A. A. Nichoson, assistant to the vice-president of The Texas Company, gave an inspiring talk on "Production for Victory." The speaker discussed the relationship of management and labor and stressed the great need for a better understanding among all citizens of this country so that the vital problems confronting the nation today and in the near future may be solved successfully. Executive officers of all local sections of engineering societies were invited to this meeting. Wm. P. Hill, chairman of the Baltimore Section, presided and J. M. Mousson, program chairman, acted as toastmaster, introducing the guests and the speaker.

Following a dinner held jointly with the A.T.E.E. on March 1 the Baltimore Section heard a talk by President Coes of the A.S.M.E. on "Scheduling of Machines for Maintenance and Maximum Use." This talk stressed the need of maintaining maximum production efficiency with anticipated breakdowns at times. The talk provoked vigorous discussion and was a timely subject at present.

GROUP AT BALTIMORE SECTION MEETING, MARCH 29

(*Left to right:* George D. Moomaw, vice-president, Rustless Iron and Steel Corp.; J. M. Mousson, chairman, program committee, toastmaster; Capt. A. A. Nichoson, assistant vice-president, and John Brown, The Texas Company, and Wm. P. Hill, chairman, Baltimore A.S.M.E. Section.)

Powder Metallurgy Subject at Bridgeport

The Bridgeport Section heard a timely talk on March 25 on the subject of "Industrial Importance of Powder Metallurgy" by Prof. Jerome F. Kuzmick, assistant director of research, Stevens Institute of Technology. The most spectacular use of powder metallurgy has been in the manufacture of metal-cutting tools approaching the hardness of the diamond. These tools have made increase in war production possible. Other uses are the making of porous metal parts which are charged with lubricants like grease or graphite; they are useful for bearings and brake and clutch linings. Extensive use is made of friction materials in ordnance vehicles such as tanks, jeeps, and gun mounts. The speaker presented valuable facts on metallurgy relating to carbide tools, especially with analysis of tungsten, cobalt, carbon, graphite, and titanium—also other metals—with history and recommendation of percentages of various ingredients to meet certain conditions to cut various metals. Metallurgists present were keenly enthusiastic in their appreciation of enlightenment on a subject filled with many problems in manufacture. This program was arranged by J. M. Lucarelle, member of A.S.M.E., program chairman and superintendent in charge of production at the Bridgeport plant of the Dictaphone Company.

Buffalo Hears Col. J. F. Walsh on Wartime Logistics

More than 1000 engineers attended the War-Production Conference at the Buffalo Section meeting of January 11. Col. James F. Walsh, chairman of the War Production Committee of the A.S.M.E., spoke on "Wartime Logistics." He stated that the President has outlined a terrific job for America's industry—the equivalent of building an Empire State building every hour or a Panama Canal every day. Commander R. S. Smith, U.S.N., resident inspector of naval materials for Buffalo, asserted that American ingenuity and engineering research will be called upon in the days ahead more than ever before to maintain production schedules despite shortages of materials.

Colorado Section Has Many Interesting Meetings

On December 16, members of the Colorado Section held a joint meeting with the American Society for Metals. G. M. Magee, research engineer of the Association of American Railroads, gave a talk on "Railroad Research" covering stress measurements—rails and bridges. This talk was supplemented by motion pictures showing many bridges and rails tested and the elaborate equipment used in these tests. On January 22 the Section heard an interesting talk by J. E. Long on "Poppet Steam Distribution System on Locomotives." The Colorado Section again met on February 26 to hear R. W. Akerlow of the Stearns-Roger Manufacturing Company speak on the subject of "Recent Trends in Designs of Boilers and Their Accessories." Starting with the design of boilers in the early nineteenth century, the lecture carried through the many subsequent developments up to a modern steam-generating plant.

Chemical Age Discussed at Detroit Section

On March 2 the Detroit Section, with 180 members and guests present, heard a most timely lecture given by H. M. Merker, superintendent of manufacture, Parke, Davis and Company, Detroit, the subject being "This Chemical Age." He spoke of the remarkable development of synthetic products, illustrating his talk with displays of various types of plastics, rubber, and other compounds which are becoming increasingly important. He explained the many products which his company produces, such as blood plasma, vitamins, sulpha drugs. The stories of their development have considerable romance behind them which was well portrayed by the speaker.

Detroit Juniors Learn About Tool Engineering

Junior Members of the Detroit Section at their meeting on March 16 heard Donald E. Jahncke, tool engineer, Plymouth Motor Corporation, talk on "Tooling for Production." He exhibited different samples and a set of operation sheets to illustrate how the tool engineers solve their problems. Discussion brought out training and educational requirements of tool engineering, which were contrasted with those proposed in a recent article in Mechanical Engineering; the possibility of use of women for tool engineers; and the place of the technically trained tool engineer.

War-Production Conference in East Tennessee

The East Tennessee Section held a successful War-Production Conference in January at Kingsport, Tenn., with 350 members and guests present. Chattanooga also held an interesting and well-attended War-Production Conference on February 11.

History of Aluminum at Kansas City

On March 26 Kansas City Section saw two motion pictures. The feature picture, "Unfinished Rainbows," depicted the history of aluminum; while the second film, "Curtiss-Wright Answers the Call for Quantity," showed the mass production of the Curtiss-Wright fighter plane.

Metropolitan Juniors Visit Ruppert Brewery

Sixty members of the Metropolitan Section of the A.S.M.E. Junior Group and their friends visited the Jacob Ruppert Brewery on March 23. They were conducted in small groups through the brewhouse, filter room, racking room, wash house, and powerhouse—ending the tour at the tap room. The meeting was in charge of P. B. Petty for the A.S.M.E. and J. G. Morrow for the Jacob Ruppert Company. This visit was instructive and interesting. The group is planning a dinner on May 25, at which A. C. Stutson will talk on "Fundamentals of Lubrication."

Cyclone Combustion at Norwich

The Norwich Section of the A.S.M.E. saw two worth-while films presented by H. E. Linsley, public-relations department, Wright Aeronautical Corporation, on March 18. These films were "Power by Wright" and "Cyclone Combustion." The film "Power by Wright" showed and described manufacture and inspection processes for Cyclone-14 engine from foundry to final test. The speaker pointed out some of the changes in procedure developed since the film was made. The second film "Cyclone Combustion," described, with the help of animated cartoons, factors affecting combustion under various operating conditions. The Norwich Section highly recommends the speaker and the films to other Sections.

Rochester Section Holds Testimonial Dinner

On March 11 the Rochester Section held a testimonial dinner in honor of Albert I. Jones, factory manager of The Pfaudler Company. Edward G. Miner, chairman of the Board of this company, spoke briefly on the career of Mr. Jones. Dr. A. R. Stevenson, Jr., one of the managers of A.S.M.E., and staff assistant to the vice-president of the General Electric Co., presented a medal to Mr. Jones in recognition of fifty years of continuous membership in the society. After dinner a speech on "Postwar Planning and the Development of New Products" was given by Dr. Stevenson. He stated that to avoid a depression after the war is over will require a great deal of advance planning which must be started now if it is to be effective. When we consider the time it has taken to tool up for full war production, it must be obvious that the problem of disentangling ourselves from war commitments to peacetime production cannot be accomplished by a simple turn of the switch. He also spoke on the development of new products which take a company into new lines of business or provide improvements in old lines.

DR. A. R. STEVENSON, JR., AT RIGHT, PRESENTS MEDAL TO ALBERT I. JONES, FACTORY MANAGER OF THE PFAUDLER COMPANY AT TESTIMONIAL DINNER OF A.S.M.E. ROCHESTER SECTION

Coal Carbonization at St. Louis

At the February meeting of the St. Louis Section Mr. Rhodes, technical director of the tar and chemical division of the Koppers Company, gave an interesting talk on the products obtained from coal by coking in by-product ovens. The talk was supplemented by a motion picture of the operation of one of the large by-product coke plants erected by the company. The largest user of coke is the steel industry, while the other by-products of coal have uses, of course, in almost all other industries.

Pressure Cabins Subject at San Francisco

An outstanding meeting on February 25 had for its speaker Dr. J. E. Younger, professor and chairman of mechanical engineering at the University of Maryland, on the subject "Fundamentals of High-Altitude Flying With Pressure Cabins." Dr. Younger stated that the fundamental idea embodied in the present

SAN FRANCISCO SECTION AT MEETING OF FEBRUARY 25 HEARS DR. J. E. YOUNGER SPEAK ON "FUNDAMENTALS OF HIGH-ALTITUDE FLYING WITH PRESSURE CABINS"

(*Left to right, standing*, Walter Kassebohm, secretary, Dean G. I. Sullivan, O. B. Lyman, V. F. Estcourt. *Seated*, Harold Avery, Dr. John E. Younger, Raymond B. Plass.)

pressure-cabin airplane was patented by a French engineer. The United States Army Air Corps, by its pioneering development of the supercharger and of the pressure cabin in 1922, and later in 1935, 1936, and 1937, was the first to make the pressure cabin practical. In 1938 the United States Army Corps was awarded the Collier Trophy for the first pressure-type airplane to fly anywhere in the world—the Lockheed XC-35.

Tri-Cities Section Enjoys War-Production Conference

The Tri-Cities Section War-Production Conference held on March 4 was a tremendous success. Tickets were sold out before the meeting. Just before the dinner another large number of applications was received. A group of from twenty to thirty had to leave, some for another dining room, and others—for home.

Western Massachusetts Hears Thornton Lewis

On March 16 the A.S.M.E. Section of Western Massachusetts held a meeting with 120 members and guests present, including members of the Springfield Section of the American Institute of Electrical Engineers. The speaker of the evening was Thornton Lewis, Deputy Chief of the Production Service Branch, on the subject of "Tremendous Trifles in Ordnance." Mr. Lewis stated that his subject might be called "The Mobilization of Brain Power for Aiding the Nation." He pleaded for help from engineers and private industry to aid in continuing the program of conversion, consisting of saving critical materials, machines, and manpower. He cited numerous examples, one of the most outstanding of which is the present use of glass gages which possess many factors of improvement over metal.

With the Student Branches

Northeastern Hears of Industry's Serious Plight

Shortage of Engineers Means Somebody Must Do Something About It

NORTHEASTERN UNIVERSITY STUDENT BRANCH, consisting of 50 members, and about 30 other students heard Dean William C. White on Feb. 18 discuss the subject "The Engineering Situation in the Immediate Future." Dean White stated that the need for engineers now is extremely acute, with the armed forces alone demanding 150 per cent of the present capacity of the 160 engineering schools in the United States. This leaves minus 50 for industry. Our industrial system will shortly experience an acute need for technically trained men. No one knows the solution, but, according to Dean White, if the industrial need for engineers becomes so bad that it affects our defense program, somebody will have to do something quickly, and that probably means that men in the armed services will be returned to industry. This has already occurred in the case of drafted copper miners who had to be returned to the mines to keep up the copper production. On March 4, 30 members of this Branch heard John B. Pugsley, professor of geology, give an illustrated talk on "National Parks" in which he told of some of the important mineral and metal deposits in those regions. On March 11 the Branch enjoyed hearing F. W. Warner, production development engineer, General Electric Company and general chairman of the Plastics Society, who spoke on the subject, "Plastics for Semistructural Applications." On March 25 a joint meeting with the student chapter of S.A.M. was held. A moving picture was shown of how England is making use of her manpower in the present war. Another interesting picture, "Wright Builds for Air Supremacy," indicated how Wright "Cyclones" are built, tested, and used.

Research in Engineering

On March 23 the ALABAMA POLYTECHNIC INSTITUTE held a meeting at which Prof. L. M. Sahag of the machine-design and mechanical-drawing department of A.P.I. spoke on the subject "Research in Engineering." This lecture covered both research in college and industry yesterday, today, and tomorrow. Plans were made for a dance to be held in the near future.

Arizona on to Mexico

The UNIVERSITY OF ARIZONA BRANCH had a meeting on March 24 at which time it was announced that tentative plans called for the Student A.S.M.E. convention at New Mexico State College near Las Cruces, New Mexico. It is planned to send five or six members to the convention from Arizona. A technicolor sound picture on "Turret Lathes: Their Operation and Use," by Gisholt Machine Company, was shown. This picture was introduced by W. C. Currie, a University of Arizona mechanical-engineering professor, who has been employed by the Gisholt inspection department for the past two summers. Branch members met on February 24 to discuss the possibilities of attending the A.S.M.E. student convention at California Institute of Technology. Chairman Fiedler reported that gasoline could be obtained for the trip by auto if five or six members could attend. Plans for the annual Engineers' Day on St. Patrick's Day were discussed. The A.S.M.E. members are to organize a soft-ball team for the mechanical-engineering department of the engineering college.

THE UNIVERSITY OF ARKANSAS at its meeting on March 29 heard Carlos Henderson speak on "Modern Automatic Weapons." He explained the operation of the gas and spring-operated types of weapons and pointed out that all automatic weapons are basically one of these two types. John Adams then discussed "The Uses of Plywood." He explained that by a method of heat-treatment with pressure, a plywood may be formed which is stronger than the original wood. Plywood has little or no expansion because of temperature change, has high strength, lightness, is easily worked and inexpensive. Ensign J. L. Thornton who was to be president of the Student Branch this year visited the meeting and gave a talk on some of his experiences while training at Pensacola, Fla. This student branch also held a meeting on March 23 at which time Henry Callaway discussed "Modern Aerial Bombs." George Dodson talked on "Plastics" explaining that there are two types—natural and artificial.

1942–1943 UNIVERSITY OF ARIZONA STUDENT BRANCH OF A.S.M.E.

The April 1 meeting of the City College Student Branch of A.S.M.E. was devoted to the presentation of student papers, the object being to select two papers to represent the college at the student convention. Papers presented were: "Adjustable Snap Gages," by Herbert Becker; "Photoelasticity," by Sol Young; "Diesel in the Air," by Henry Fleigler, and "High-Speed Indicators," by Lawrence Lief. The first prize was won by Lawrence Lief and second prize by Herbert Becker. The prize winners will be the guests of the Branch at lunch and dinner and will represent it at the April 17 convention.

C.C.N.Y. Branch meeting, which was on March 11, was devoted to a lecture on "Properties of Metals at Elevated Temperatures" by Richard F. Miller of U. S. Steel. The effect of high temperatures on other properties, such as heat conductivity, was also discussed and the lecture was concluded by a brief discussion of the effects of alloying metals on creep and oxidation resistance. This Branch held its semi-annual dance on March 20. Over sixty couples were present. A "Take-It-or-Leave It" quiz contest in which the faculty participated was the feature of the evening. All prize money and money collected at the check room was donated to the Red Cross.

University of California Branch held its spring installation banquet on Jan. 27. Jack Miller was made chairman for the spring semester. Les Burgess, the past chairman, was presented with a gavel and a book as recognition of his good work during his term in office. Dean McLaughin concluded the evening with an interesting story of his recent trip to Peru and his experiences in connection with an American-owned mine there. Many members accepted his invitation to go to his home after the meeting to see the slides he had taken while in Peru.

Aluminum Takes the Screen

California Institute of Technology Branch members held their meeting on March 8 at which time they saw two motion pictures, "Aluminum-Fabricating Processes" and "How to Machine Aluminum."

Dad's Night at Case Branch

Case School Branch at its Dad's Night meeting on March 10 had to elect a new president and a vice-president because of losing the former ones to the Army Air Corps. A. T. Colewell, vice-president of Thompson Aircraft Products Company, spoke on "Late War Engineering Developments" which was confined chiefly to aircraft problems. This Branch accepted the invitation of Dr. H. B. Osborn to make an inspection tour through the Ohio Crankshaft Company. This tour was made on April 1 and enjoyed by all who attended.

Clarkson College Student Branch at its meeting on February 18 discussed plans for sending a delegate to Syracuse to the annual A.S.M.E. student convention. Two short movies were shown. The first, entitled "Years of Progress," dealt with the Chrysler Company's engineering laboratories, and the second, "Nickel Mining," with methods of production at the Sudbury Ontario Nickel mines.

University of Delaware Branch held a meeting on Jan. 11 to hear Roger W. Fulling of the du Pont Company speak on "Human Engineering." He explained what industry expected of an engineer and how to prepare oneself for an engineering position in industry. This Branch saw a movie entitled "Wheels Across Africa and Wheels Across India."

The Student Branch of Duke University held its meeting in March. New officers were elected. A welding class has been started which is a new project at this University with Prof. E. S. Theiss, honorary chairman, and Joe Myers, a student, as instructors. R. G. Miller, representative of the Lincoln Arc Welding Company, spoke at one of the March meetings, explaining and illustrating the contest his company is conducting. A number of Duke University students are planning to enter the contest.

Trip to Jacksonville

University of Florida Branch on Feb. 6 held its meeting at which two student members were the speakers. The topics were "Modern Inventions of War" and "Tooling at Willow Run." On March 12 the Branch trip committee proposed an inspection trip to Jacksonville to look over the gas plant, a foundry, and the shipyards. Two interesting talks were given by student members. The first one, entitled "Aircraft Launching and Recovery on Board Ships Other Than Aircraft Carriers," was presented by an ex-Marine who has seen duty with the fleet during his period of enlistment. The second talk was about "Women in Wartime Industry."

A group of 21 members of the Florida Student Branch inspected three Jacksonville, Fla., industrial plants on April 3. In the morning they visited the Florida Machine and Foundry Company; after lunch, the shipyards at the St. John's River Shipbuilding Company; and in the late afternoon, the Jacksonville Brewing Company.

Illinois Institute of Technology Branch on Feb. 23 held its regular meeting. After the business meeting a movie was shown on "Tanks" which described the production of tanks in the United States. This Branch held its first meeting of the second semester on March 17 at which the following films were shown: (1) "Radium," interesting and educational; (2) "Television," indicating what the future has in store for us; (3) "Japanese Relocation," showing the present situation and how it is being handled.

University of Kansas Branch at its meeting on Feb. 4 heard a good talk on "Postwar Problems" by Prof. R. H. Wheeler of the psychology department. Professor Wheeler explained his experiments with antics of hot and cold rats showing the comparison of peoples' living in different climates, their sex habits and their vitality, thus bringing an out-of-the-ordinary talk to engineers. This Section met on Jan. 7 with the A.I.Ch.E. to witness a showing of an illustrated picture on "Arc Welding" produced by the Walt Disney studios.

Tempest Over Tunis

University of Kentucky Branch members of the A S.M.E. were treated to two motion pictures on February 19. The picture on Tunisia showed the customs of the people and the sights of this country. The "Oil for Aladdin's Lamp" was valuable and timely as it showed how a great deal of research work is being done by one of America's leading oil companies. The experiments conducted with petroleum were unusually interesting. On February 26 the members listened to a talk by Maurice Mitchell on "The New Road Testing Machine at the Highway Laboratory." This machine involves a number of ingenious mechanical principles particularly in the gearing and the power supply.

Initiates Wear Metal Gears For Necklaces

Louisiana State University Branch at its meeting on February 18 opened initiation week with an informal smoker. Prof. G. F. Matthes, honorary chairman, gave a short and interesting talk on "What Benefits Are Derived From A.S.M.E Membership." As an advertisement and initiation the initiates were instructed to wear around their necks metal gears made in the machine shop and a blueprint copy of a shamrock with the letters A.S.M.E. in each corner. This Branch held its popular initiation banquet on March 4. Included among the 50 guests present were Dean Lasalle of the college of engineering, professor emeritus Hamilton Johnson, associate professor H. W. Waterfall, and Professor Whipple of the sugar and heat-engineering department. Professor Waterfall gave an interesting talk on "India, the Country of Many Peoples."

The University of Louisville Branch held a meeting for the entire school on Feb. 8. Col.

MEMBERS OF THE A.S.M.E. MONTANA STATE COLLEGE STUDENT BRANCH

James C. Walsh, chairman of the A.S.M.E. War Activities Committee, was introduced by Dean Wilkinson and spoke on "Logistics—the Science of Survival." This Branch also had a meeting on March 18 when they saw a film on "Flow" showing the manufacture and use of valves.

Gas Turbines Discussed at Milwaukee

On March 10 the Milwaukee Section of the A.S.M.E. joined with the A.S.M.E. Student Branch at Marquette University to hear J. Algot Johnson, B.S., mechanical engineering, University of Kansas, discuss "Gas Turbines," and Mr. Dahlstrand of Allis Chalmers talk on "Steam Turbines." The use of gas turbines in locomotives and in ships and the process for octane gas production were explained. In the course of the talks it was stated that the development of an efficient turbocompressor had made present gas turbines possible.

The Marquette University Branch now has a chapter of Pi Tau Sigma, honorary mechanical-engineering fraternity. On Nov. 12 the Marquette Pi Delta Chapter of the Pi Tau Sigma Fraternity was installed as a part of the national convention proceedings at the University of Minnesota.

The University of Maryland Branch of the A.S.M.E. held its annual monthly meeting on February 17. Representatives for the junior and sophomore classes were elected. The students voted to appropriate a sum of money for the Eichland Memorial in memory of Dr. Eichland, late professor of physics. At this meeting films were shown on the PT-19 through the courtesy of Lockheed, and Prof. W. P. Green spoke.

Awards Made at Nebraska

University of Nebraska Branch met on March 17. Three student papers were presented on (1) "Water Softening;" (2) "Welding to Replace Riveting on Tainter Gates;" (3) "Wood-Veneer Construction in Aircraft." A vote was cast to select one member each from the junior and senior classes to receive the senior award of membership into the A.S.M.E. as a junior member, and to receive the junior award of a Marks' "Mechanical Engineers' Handbook."

This Branch heard a report on the subject of "The History of Marine Engineering" on March 31. A guest speaker from the Lincoln Elastic Stop Nut factory gave a report on the history and development of the elastic stop nut and of its many uses in aircraft, gun, and tank construction.

University of Nevada Branch voted not to have an Engineers' Day this year because of the fact that cadets at the schools are using the laboratories and this would necessitate cutting down on exhibits. A committee to provide entertainment such as lectures, moving pictures, or other suitable substitutes was named.

Newark College of Engineering Branch had an unusually successful meeting on March 7. Dr. F. D. Carvin, Prof. H. E. Walter of the mechanical-engineering department of the college, and Wm. G. Christy, a member of the A.S.M.E. Council and a manager of the Society, were present. Mr. Christy is smoke-abatement engineer of Hudson County, N. J. The speaker of the evening was Captain Thomas Shaughnessy of the Army Ordnance Department in Washington, D. C. Captain Shaughnessy's talk was supplemented by three reels of sound motion pictures of the Ordnance Department. He told of the divisions of the department, their functions, and traced the path of an Army trainee as he progressed. The speaker is specially recommended for other Student Branches.

The University of New Hampshire held its meeting on March 24. The first speaker, Harold Hoch, predicted some of the probable developments in automotive design after the war, such as lighter plastic bodies, lighter, more efficient engines, and slow-to-moderate car speeds. Quentin Theroux gave an account of war work done by a heavy-machine shop in Portland, Maine, where he worked during last summer. Herbert Wuth spoke on the findings of several industrial plants regarding the use of music to relieve nervous strain. It has been found that in almost all cases, music has increased production, especially when the work is monotonous. The annual St. Patrick's Day dinner was held on February 24 with a dinner followed by a talk on "Scrap, Junk, and Engineering Specifications," by Dr. Daniel Eppelsheimer, director of the engineering experiment station.

New York University Branch (Evening Branch) members and a number of visitors enjoyed an illustrated talk by Fred Uhl, sales engineer, Westinghouse Electric and Manufacturing Company. This was a joint meeting of the electrical and mechanical engineering societies. The subject of the talk was "Transporation Problems—Present and Future." Mr. Uhl used the Independent Subway System as the basis for his remarks.

War Charities Carnival

University of Notre Dame Branch held a biweekly meeting on March 18. At this meeting two technical films were shown, "Boeing Flying Fortress" and "Hamilton Propellers." The progress of students preparing talks for the Spring Conference at Northwestern University was reported. Various club members discussed plans for a War Charities Carnival. The mechanical engineers evinced their whole-hearted support by volunteering to erect and maintain a booth at the affair.

Synthetic Materials

Ohio State University Branch met on Friday, February 19, and S. M. Marco, honorary chairman, gave further information concerning the A.S.M.E. Speaking Contest. The speaker, William MacNevin, department of chemistry, spoke on the subject "The

THE UNIVERSITY OF NEW HAMPSHIRE A.S.M.E. STUDENT BRANCH

(*Left to right, first row:* Dyson, Nye, Sullivan, Robbins, Grube, Kelley, Sanne; *second row:* Foster, Baker, Murphy, Milas, Jenkins, Quimby, Sanborn; *third row:* Chase, Colby, Hewitt, Cunningham, Neal, Hoch, Wuth, Harriman, Otis; *fourth row:* Sleeper, Herrick, Russell, Roy, Day, Theroux, Deming, King, Curtis, Orton.)

PURDUE UNIVERSITY STUDENT BRANCH OF A.S.M.E. AT MEETING OF FEB. 15

Molecule Goes to War." He explained the importance of new chemical developments in relation to the war and supplemented his talk with a large display of plastics, synthetic fibers, and synthetic rubbers. He gave an especially interesting discussion of the development of the synthetic-rubber program which the Government is sponsoring to relieve the rubber shortage. This Branch held its last meeting of the winter quarter on March 5. Charles Negulici gave a summary of the year's athletic activities. The mechanical engineers' teams are very proud of having won league championships in basketball, baseball, and bowling; they have also taken runner-up position in football.

The Oklahoma A.&M. Branch held a meeting on March 29 at which candidates were presented for engineering queen. This Branch held a joint meeting with the A.S.C.E. on March 22. A film was shown on "Steel" distributed by the American Institute of Steel Construction. A business meeting was then held.

"Hap" at Pittsburgh

The University of Pittsburgh Branch held a unique meeting on March 17. Mr. Stickel or "Hap" as he is known on the campus related experiences he had had while traveling around the country to different meets. Mr. Stickel is head track coach of the University and has been a very prominent figure in track for many years. On March 31 this Branch met and T. G. Beckwith, honorary chairman, announced that the University of Cincinnati, the University of Akron, and Carnegie Institute of Technology had all replied that they would send representatives to the coming student convention at Pittsburgh.

Pratt Institute Branch held a business and organization meeting of their members on March 4. This was their second meeting, which was primarily for the members of the new freshman class who wished to apply for membership.

Hitler Doing the Lambeth Walk

The Purdue Student Branch held a "Get-Acquainted Meeting" on February 10 in the Faculty Lounge of the Purdue Memorial Union. Prof. H. L. Solberg, head of the Mechanical Engineering School, gave a talk on the organization and its advantages. The members and guests were entertained by the showing of motion-picture films, "Tree in a Test Tube," "Hitler Doing the Lambeth Walk," and "The Airscrew."

On March 15 Purdue Branch had a meeting which was attended by 150 members and guests. The picture "Target for Tonight" was shown. This film presented in detail an actual air raid over Germany by the Bomber Command of the Royal Air Force. This Branch sponsored an inspection trip through the new Hall of Music on March 24. Mr. Dittamore, manager of the Hall of Music, served as guide. On March 30 Merton Clevett, senior in mechanical engineering, won the first prize for his speech "Submerged-Combustion Steam Generation." David M. Badger won the second prize with his talk, "Grain in Photography." Third prize was awarded Albert S. Goodrich, who spoke on "Precision Instrument Gears." Mr. Clevett, the winner, will represent the Branch at the regional meeting to be held at Northwestern University on April 12 and 13. He will also be eligible to share in cash prizes which are to be awarded.

R.A.F. at Queens

Queen's University Branch on March 1 started a project of a machine shop for their members. A prize will be given the group turning out the finest piece of work. The second round of their public-speaking contest was started by Bill Sweet, who gave an interesting talk on "Aluminum Forgings." Stuart Clark gave a talk on the engineering involved in boxing our war materials before preparing for overseas shipment. On March 3 this Branch enjoyed talks given by guest speakers, Flight Lieutenant Peat of the R.A.F. on "A Résumé of a Navigator's Day," followed by Major General Schmidland who gave a talk on his experience in the Army Engineering Branch. Prof. L. T. Rutledge topped off the evening by relating a few short stories pertaining to his past experience in the engineering field.

University of Santa Clara Branch at their meeting on March 10 viewed the picture "Bridging San Francisco Bay" with the visiting civil engineers in that city. This picture showed actual construction of the Bay bridge, including the cable spinning. Jim Selna gave a short talk on "Scavenging" and explained various methods of scavenging in Diesel engines.

Army Air Force Films

Southern Methodist University Branch at its first meeting of section B featured three films. Two were from Curtiss-Wright Aircraft Company. One entitled "Wright Builds for Air Supremacy" showed the building of the Wright aircraft engine from single-parts manufacture up to final assembly and testing. The other, "Cyclone Combustion," gave a detailed description of combustion showing detonation and efficiencies due to fuel-air ratios. The third film was on the "Sikorsky Helicopter." Prof. C. H. Shumaker gave a talk describing the operation of the machine. On March 6 this Branch held a joint meeting with the North Texas Branch for the purpose of seeing three Army Air Force films entitled (1) "Parachute School Training," (2) "An Air-Borne Mission," (3) "Woman Power." The first gave the complete training of a paratrooper from induction to graduation. "An Air-Borne Mission" showed the most efficient way of moving men, materials, supplies, guns, and ammunition by plane. The film on "Woman Power" showed how women have replaced men in the machine shops of industry. It indicated their efficiency and their quick adaptability to new machines and operations.

University of Tennessee Branch meeting of March 3 covered the preliminary presentation of papers to be presented at the annual A.S.M.E. Student Branch meeting. W. K. Stair presented a paper on "Economic Factors Determining the Location of Watts Bar Steam Plant," and L. F. Chandler one on "The Taylor Compressor." Mr. Chandler was awarded first prize.

Baseball and Aircraft at Texas

The University of Texas Branch with a touch of spring in its veins held a meeting on February 8 when members interested in baseball signified their interest in making up a team. After the regular business meeting a training film, "Aircraft-Engine Carburization,"

PROF. H. L. SOLBERG, HEAD OF THE MECHANICAL ENGINEERING SCHOOL AT PURDUE UNIVERSITY ADDRESSING MEETING OF STUDENT BRANCH OF A.S.M.E. ON FEB. 10

QUEENS UNIVERSITY STUDENT BRANCH, A.S.M.E.

was shown; also a comedy film "Spinning Mice." At the February 15 meeting H. L. Kent, assistant professor of mechanical engineering and honorary chairman of the meeting, advised that students attending the student convention in Dallas on April 9 would be given credit for the noncredit course. Mr. Leach then spoke on "Magnesium—Its Process of Manufacture and Its Uses," discussing different processes of production. On Feb. 22 the Texas Branch met again and plans were made for a picnic on March 6. Norman Wheeler presented a paper on "The Hughes Tool Company" describing the plant layout, products manufactured, and machines that were of general interest. A film on "The Control of the Commercial and Military Air Travel in the United States" was shown.

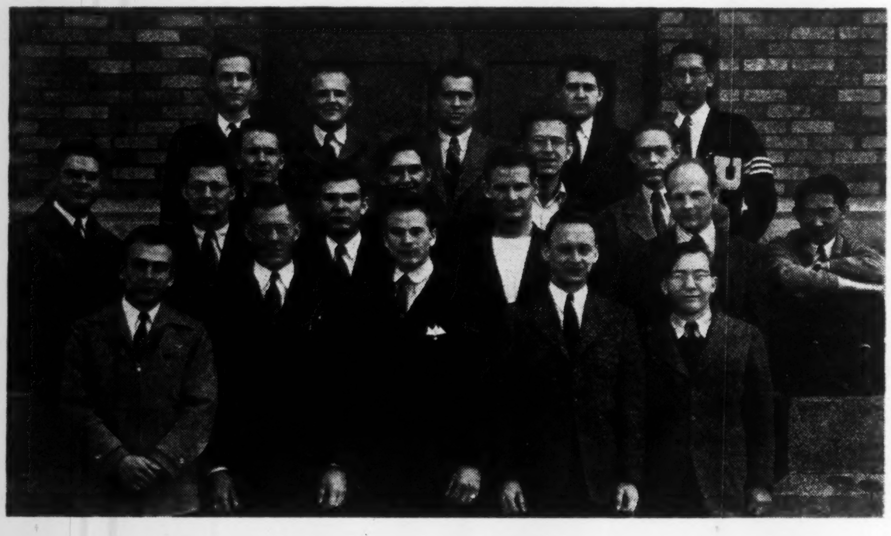
On March 1 the University of Texas Branch held a meeting at which Mr. Wilbern spoke on "Bull." He advised engineers not to wall themselves up too much with what they are interested in—but to watch the social side of industry also. At the March 22 Meeting of the Branch H. L. Kent, Jr., was made honorary chairman. A film on the "Construction of the Boulder Dam" was shown on the preparation of the dam site, the building of the cofferdams, the digging of the diversion tunnels, the construction of the dam proper, and the construction of the hydroelectric plant. On March 29 this group met to hear the contestants for the Dallas meeting on April 20. Papers presented were as follows: Maurice Adam, on "Vibration Measuring Instruments;" Charles Townsend, on "The University of Texas Dehydration Process;" Bill Staton, on "The Influence of Storage Conditions on the Physical Properties of Lignite." Final elimination contest will be held on April 12. We note attendance jumped from 14 on March 16 to 37 on March 29. Good work, Mr. Staton.

Tufts College Branch on February 9 held a very timely meeting on the subject of "War Gases and Chemicals" with Dr. P. Doleman of the chemistry department as guest speaker. The audience was astounded to hear that it is quite impossible to wipe whole cities out by gas at present, and possibly even in the future. He also stated that the most lethal of gases now used is chlorine and not the much spoken of mustard gas.

Tulane University Branch enjoyed its fifth meeting on February 23 when interesting talks were given by three mechanical engineering seniors: Ben Flake on "Injector Carburetors for Aircraft;" Howard Marx on "Some of the Latest Advancements in Blind Flying;" and John Martinez on "Various Types of Superchargers." A film on "Durability of Concrete" was also shown.

Vermont to Visit Syracuse

The **University of Vermont Branch** had its first meeting of the current semester on March 4 at which Prof. R. G. Chapman was in charge. Plans for the coming meeting of the A.S.M.E. Branches at Syracuse University in April were discussed and it was decided that the Vermont Branch would send a speaker to the meeting. On March 23 E. S. Boyden gave



SENIOR CLASS—SPRING, 1943, ALL STUDENT MEMBERS OF A.S.M.E. AT THE UNIVERSITY OF UTAH

(*Left to right, first row:* Nielsen, Knight, Olsen, Sumnicht, Cohenour; *second row:* Bates, Hicks, Berrier, Van Derck, Middleton, Watanabe; *third row:* Foulger, Doulsin, Fowler, Lucas; *fourth row:* Connell, Nibley, Bryner, Purlsey, Gebhart.)

UNIVERSITY OF TEXAS A.S.M.E. STUDENT BRANCH a brief talk on the subject he and H. E. Crosby, Jr., are preparing for the convention at Syracuse.

Personality Meter Hot Stuff At Washington Branch

WASHINGTON UNIVERSITY STUDENT BRANCH on March 6 gave their annual "Steam Men's Strut." This was held in the engineering laboratory amid engines, generators, and testing machines. The novelty of the dance was a "Personality Meter." The swinging hand on the machine's face swung around until it stopped on "apple polisher," "hot stuff," "bonehead," "beautiful but . . . . ," and many other descriptive titles. Also of interest to the guests was the Corliss engine which was set to turn over slowly. Its large flywheel was decorated with lights producing a novel effect. The rest of the laboratory was likewise decorated with colored lights. This Branch announces its first and only woman member, Delphine Kansteiner, who has enrolled in mechanical engineering and proclaims that she is one of three such woman students in the country.

Banquet at Wisconsin

UNIVERSITY OF WISCONSIN BRANCH held a banquet and dinner on February 24. After the dinner a combined meeting with the Rock River Valley Section of the A.S.M.E. and the A.S.M.E. and S.A.E. student branches of the University of Wisconsin in co-operation with the Madison Technical Club was held. The guest speaker of the evening was Col. Fay Dice, who is in charge of radio instruction at Truex Field. Colonel Dice's subject was "The Importance of Air Power in the Present War." He emphasized five "musts" for American action: (1) "Co-operation With the Allies;" (2) "Placing Campaigns in the Hands of Capable Strategists;" (3) "Unified Commands in Each Theater of War;" (4) "Effective Air Power;" (5) "An Aggressive Way of Thinking That Has in It No Worry About Giving Up."

New London Bridge at Yale

YALE UNIVERSITY BRANCH held a joint meeting on Feb. 9 at which 20 visitors from the New York, New Haven, and Hartford Railroad engineering department were present. The showing of a Connecticut State Highway Department film, "The New London Bridge," was given and a lecture on this picture delivered by Mr. Bushell of the Highway Department. On Feb. 23 the student presentation of papers was as follows: "The Development of the Airplane Propeller," by J. C. Alford; "Motive Power for the High-Speed Trains of Today," by J. R. Barber; "Trials and Tribulations of an Apprentice-Boilermaker," by L. B. Brockett; and "Ship Construction Welding," by A. E. Dohna. On March 2 papers were given by R. G. Dyke on "Learning From Experience;" by J. E. Eggleston on "Music in Industry;" by L. H. Freiberg, Jr., on "Description of a Ship Model Basin;" and by R. D. Furse on "Summer Work in a Scale Plant." This Branch has held three meetings during March. On March 16, student presentation of technical papers in the Senior M.E. seminar was as follows: "Modern Aircraft Maintenance," by C. C. Graves; "Corrosion in Pipe Lines," by R. E. Jacobson; "Diesel Aircraft Engines," by J. S. Greacen; "Collapsible Bridges," by F. H. Finley; and "Marine Operation—New York Harbor," by C. D. G. King. On March 23 technical papers were presented by J. A. McCurdy on "Model Making as an Aid to Shipbuilding;" W. H. Millan on "Difficulties Encountered in Designing Continuous-Strip Mills;" R. A. McIntosh on "Modern Rolling Mills;" E. S. Tishman on "Function and Installation of a Preventive Maintenance System;" and F. J. O'Toole on "X-Ray Tubes." On March 30 a continuation student presentation of papers was given as follows: (1) "The French Battleship 'Richelieu,'" by P. W. Lyall, (2) "Air Cargo Transportation," by A. Morse, Jr., (3) "Contra-rotating Propellers," by N. F. Porto, (4) "The Diesel Engine," by G. R. Provo, (5) "Early Attempts at Flying," by P. D. Register.

Correction

ATTENTION has been called to an error in Table 2, page 189, of the article "Principal Characteristics of the Important Textile Fibers," by Werner von Bergen, which appeared in March issue of MECHANICAL ENGINEERING.

The value of the modulus of elasticity for cotton should be 0.7×10^6 and not 7.1×10^6, as printed.—EDITOR.

Engineering Societies Personnel Service, Inc.

These items are from information furnished by the Engineering Societies Personnel Service, Inc., which is under the joint management of the national societies of Civil, Electrical, Mechanical, and Mining and Metallurgical Engineers. This Service is available to members and is operated on a co-operative, nonprofit basis. In applying for positions advertised by the Service, the applicant agrees, if actually placed in a position through the Service as a result of an advertisement, to pay a placement fee in accordance with the rates as listed by the Service. These rates have been established in order to maintain an efficient, nonprofit personnel service and are available upon request. This also applies to registrants whose notices are placed in these columns. All replies should be addressed to the key numbers indicated and mailed to the New York office. A weekly bulletin of engineering positions open is available to members of the co-operating societies at a subscription of $3 per quarter or $10 per annum, payable in advance.

New York	Boston, Mass.	Chicago	Detroit	San Francisco
8 West 40th St.	4 Park St.	211 West Wacker Drive	100 Farnsworth Ave.	57 Post Street

MEN AVAILABLE[1]

MECHANICAL ENGINEER, American of Japanese extraction, honor graduate with one year of graduate study. Experience in college teaching. Now employed, but desires position which will more effectively utilize training. Me-799.

MECHANICAL AND ELECTRICAL ENGINEER, 42, extensive industrial and research experience, unusual analytical ability, mature judgment; can improve product quality and inspection; desires position in technical, product quality, or inspection control department. Me-800.

POSITIONS AVAILABLE

PLANT SUPERVISOR, graduate, who will have supervision over the operation of several power plants, including one 30,000-kw pulverized-fuel-fired 450-lb station and one 20,000-kw, 650-lb stoker-fired installation. Several older power plants and about 10,000 kw of hydro capacity are also included. Must have several years' recent experience in the operation of modern, medium, or high-pressure, steam stations. Salary open. Location, South. W-954.

PERSONNEL MAN who is familiar with labor laws, including compensation insurance, and who has made some study of the Manning Tables; must also have had hiring experience. Company operates a variety of automatic machines which are maintained and tooled in company's machine shop. Location, Connecticut. W-1974.

PLANT SUPERINTENDENT. Must have a thorough technical training, mechanical experience, and be capable of handling routing, planning, and estimating of machine-tool parts. Apply by letter, giving complete data and indicating salary desired. Connecticut. W-1982.

ASSISTANT CHIEF ENGINEER with knowledge of the design of air compressors and compressors for refrigeration, and possibly of semi-hermetic compressors for refrigeration. Must have background in shop and design work, and some applicational experience. Salary, to $5500 a year. New York State. W-1987.

MECHANICAL ENGINEERS, 38–50, for postwar product-development work. Should have had considerable experience with one of the following: cranes, hoists, or material-handling equipment. Permanent. Salary open. Location, New York, N. Y. W-1997.

INDUSTRIAL ENGINEER, 37–45, who has a thorough knowledge of production, costs, and methods, to manage a small process plant in southern Connecticut. Salary, $5000–$6000 a year. Permanent. W-2002.

MECHANICAL ENGINEER experienced in the fields of recording pyrometer and thermometer maintenance and who also has knowledge of machine development. Salary, $4200 a year. Location, Connecticut. W-2004.

MECHANICAL ENGINEER with considerable electrical experience, to operate two steam plants, one for a hospital and one for a laundry, together with the supervision of refrigeration from imported ice; the operation of two incinerators, and general direction over the black smith, carpenter, paint, plumbing, and sheet-metal shops. Salary, $3800 a year for a 40-hour week, plus overtime to 48 hours. Location, Louisiana. W-2015C.

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[1] All men listed hold some form of A.S.M.E. membership.

Mechanical Engineers, graduates: (*a*) With considerable experience in the general design of machinery. Specialized experience in the field of chemical process equipment desired. (*b*) Conversant with the design of machines and machine parts, such as gears, bearings, shafts, etc. (*c*) With experience in the design of pressure vessels would be desirable; should be able to estimate costs and understand how to figure plate thicknesses and sizes to meet given conditions. Salary open. Location, New York, N. Y. W-2021.

Industrial Engineer, 35–45, preferably with some practical machine-tool operation experience, to install and supervise the planning and scheduling of work in a high-precision instrument plant. Must be forceful but tactful in handling personnel and be able to co-ordinate departmental work. Permanent. Salary, $5000–$7000 a year. Location, Maryland. W-2024.

General Manager for a small machine-tool manufacturing plant. Must have had previous experience as Factory or General Manager in similar plant. Salary, about $10,000 a year. New York State. W-2025.

Graduate Mechanical Engineer, young, experienced in tool, jig, and fixture design and familiar with machine tools and machining operations, especially milling and broaching machines. Will eventually head up the manufacturing methods department. Will be required to supervise the making of the tools and fixtures in outside plants. Permanent. Location, New York State. W-2058.

Sales Manager, 40–50, experienced in merchandizing home appliances, organizing and directing sales activities, establishing sales policies. Will supervise the handling of war-contract correspondence, quotations, etc., organize and direct all sales activities of the company, including distribution, sales promotion, advertising, market research, and postwar planning. Salary, $8000–$10,000 a year. Location, Ohio. W-2063.

Mechanical Engineers, 26–45, graduates, with five to ten years' experience in chemical-plant layout, design, and construction. Work will also involve specifications for and selection of equipment. Could also use chemical-plant designer-draftsmen. Salary, $3000–$6000 a year. Pennsylvania. W-2078.

Tool and Methods Engineer to supervise department keeping records for tool and methods control; locate sources of supply, place orders, and follow up procurement of tools made on the outside. Also follow up on tools made in plant and supervise group of trouble shooters. Salary, $4500–$5000 a year. Location, Massachusetts. W-2100.

Engineers. (*a*) Chief Mechanical Engineer for company manufacturing large electric motors and generators. Will be in charge of design and drafting room. Salary, $6500–$7500 a year. (*b*) Chief Supervisor of Testing and Inspection. Above experience essential. Salary, $5500–$6000 a year. Location, northern New Jersey. W-2108.

Factory Cost Accountant for small machine shop manufacturing precision instruments. Permanent. Salary, $4000–$5000 a year. Location, New York, N. Y. W-2127.

Machine Tool Designer, graduate engineer, with about ten to fifteen years' experience in machine design. Desire man experienced in the design of automatics, screw machines, and turret lathes. Salary, about $7000 a year. Will be in complete charge of machine designing for company. New York, N. Y. W-2129.

Engineers. (*a*) Industrial Engineers experienced in accounting, general organization setup, procedures, etc. Must be able to co-operate with others in group. Company manufactures airplanes. Salary, $7000–$8000 a year. (*b*) Junior Industrial Engineer with same experience as above. Salary, $5000 a year. New York State. W-2130.

Design Engineer, graduate mechanical, thoroughly practical and experienced in creative mechanical-development work with executive ability and unusual inventiveness. Will head engineering department. Permanent, with exceptional opportunity for American citizen. Salary open but substantial. Location, Indiana. W-2131C.

Quarterly of Applied Mathematics to Be Issued by Brown University

IT HAS been announced that a *Quarterly of Applied Mathematics* is to be published under the auspices of Brown University.

Mathematical analysis is one of the most powerful tools of the engineer in the solution of the practical problems of design. Its contributions have been greatest in those fields where intuition fails as, for example, in problems of the strength of thin-walled structures. In every instance requiring refinement of design as regards weight, strength, or efficiency this tool is indispensable. Engineers are therefore keenly interested in the recent announcement of the establishment of the *Quarterly of Applied Mathematics* under the sponsorship of Brown University.

The new journal has been founded primarily to meet the needs of mathematicians and engineers whose interests include the application of advanced mathematical methods to the solution of physical or engineering problems. It will publish original papers of high scientific standard connected with engineering work, expository articles, short scientific notes, and reports on progress made in other countries. While it is not the purpose of the Quarterly to publish experimental results, mathematical contributions which have an intimate connection with application in industry or practical science will be welcomed. The editors state that "the ideal contribution to our pages would be one in which advanced and general mathematical methods lead speedily to results which are in close agreement with experiment, and which are of high importance, either in direct practical application or as an illumination of interesting phenomena hitherto unexplained."

The *Quarterly* is edited by H. L. Dryden, T. C. Fry, Th. von Kármán, J. M. Lessells, W. Prager, I. S. Sokolnikoff, and J. L. Synge, with the collaboration of H. Bateman, M. A. Biot, L. N. Brillouin, J. P. Den Hartog, K. O. Friedrichs, J. N. Goodier, F. D. Murnaghan, W. R. Sears, R. V. Southwell, G. I. Taylor, and S. P. Timoshenko. It is intended to publish four issues annually, of about 80 pages each. The first issue will appear in April, 1943. It includes articles relating to fluid mechanics, elasticity, and electrical engineering.

Engineers are invited to lend support to this new venture by contributing articles within its field and by subscribing to it. The subscription price for the Quarterly is $6 per year. Subscriptions should be addressed to: *Quarterly of Applied Mathematics*, Brown University, Providence, R. I.

Dr. Irving Langmuir Elected Honorary Member of the British Institute of Metals

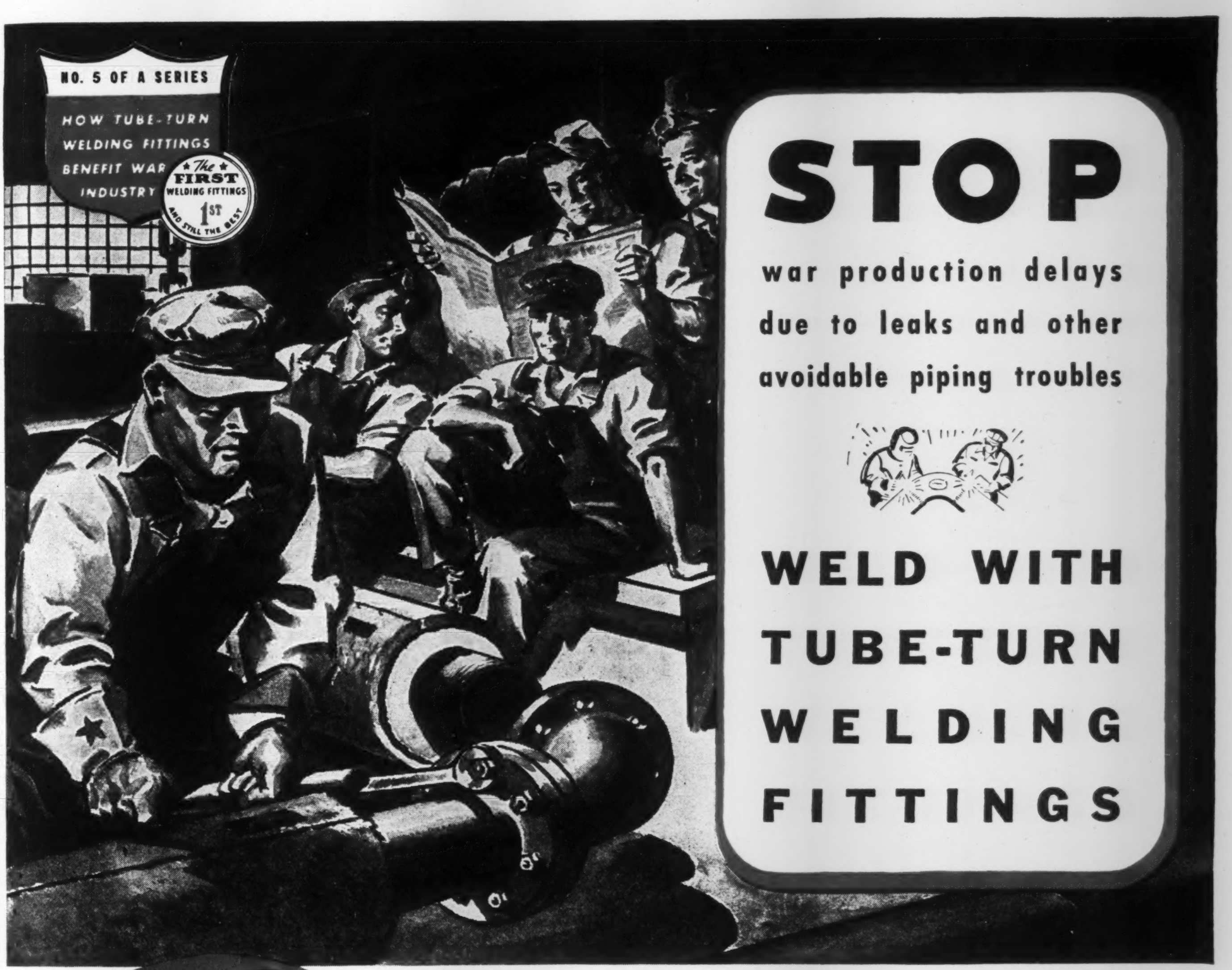
DR. Irving Langmuir, associate director of the General Electric Research Laboratory here, has been elected to honorary membership in the Institute of Metals, of London. Notification of this honor was given in a letter to Dr. Langmuir, winner of the 1932 Nobel Prize in Chemistry, from the Institute's secretary, G. Shaw Scott.

Though Dr. Langmuir has not recently engaged directly in the science of metallurgy, his work has had considerable indirect effect. His investigations on surface films have been applied to great advantage in connection with the flotation process used in separating metals from ores. His point of view as to the behavior of atoms and molecules on surfaces has proved helpful in the study of metals. He has worked on the emission of electrons from metals when heated. Other researches have concerned the effects of gases in metals, of which the importance has only recently been recognized.

The Institute of Metals, which is international in character, has only two honorary members at present. One is Professor C. A. F. Benedicks, director of the Metallographic Institute, Stockholm, Sweden, who, on a visit to the United States a few years ago had many active discussions with Dr. Langmuir regarding grain growth in metals. The other is Dr. A. M. Portevin who was professor of metallurgy in the Central School of Arts and Manufactures in Paris before German occupation.

HAROLD V. COES, PRESIDENT, A.S.M.E. SPEAKS AT THE BANQUET OF THE ENGINEERING INSTITUTE OF CANADA HELD DURING ITS 1943 ANNUAL MEETING

(*A.S.M.E. News continued on page 394*)


NO. 5 OF A SERIES
HOW TUBE-TURN WELDING FITTINGS BENEFIT WAR INDUSTRY
The FIRST WELDING FITTINGS 1ST AND STILL THE BEST

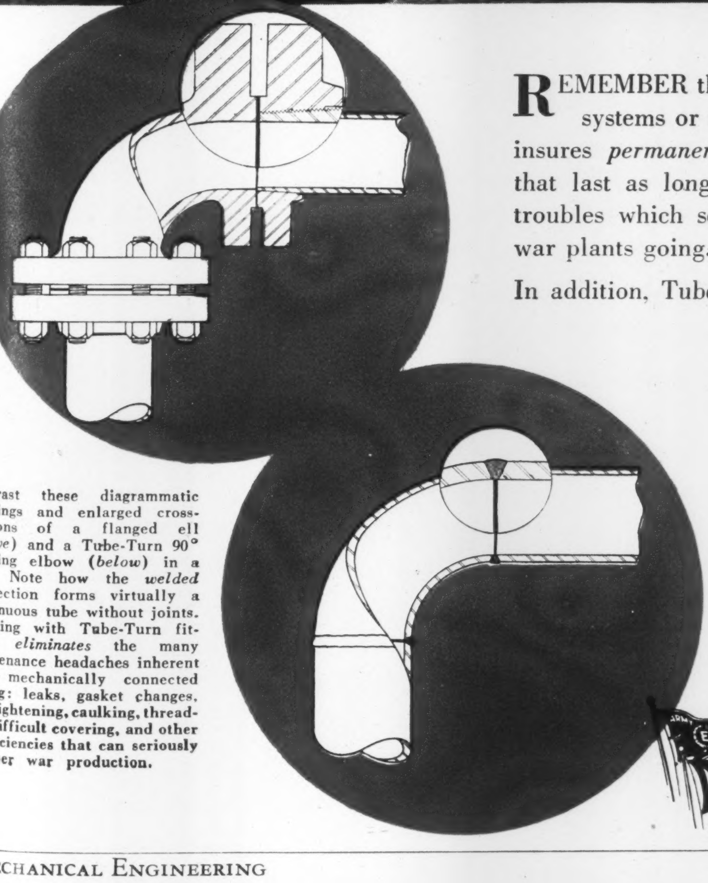
STOP

war production delays due to leaks and other avoidable piping troubles

WELD WITH TUBE-TURN WELDING FITTINGS

REMEMBER these common-sense facts before you install new piping systems or replace old sections: welding with Tube-Turn fittings insures *permanently leakproof, trouble-free joints* and better fittings that last as long as the pipe itself. You banish many maintenance troubles which seriously interrupt the vital *piping arteries* that keep war plants going.

In addition, Tube-Turn welding fittings give you *greater strength and safety;* uniform wall thickness, for *easier, faster alignment and welding;* compact piping layouts that *save space, weight and installation time;* smooth inner walls that mean far *better flow, less corrosion* and *greater piping efficiency.*



Contrast these diagrammatic drawings and enlarged cross-sections of a flanged ell (*above*) and a Tube-Turn 90° welding elbow (*below*) in a line. Note how the *welded* connection forms virtually a continuous tube without joints. Welding with Tube-Turn fittings *eliminates* the many maintenance headaches inherent with mechanically connected piping: leaks, gasket changes, bolt tightening, caulking, threading, difficult covering, and other inefficiencies that can seriously hamper war production.

TUBE-TURNS (INC.), LOUISVILLE, KY. *Branch offices:* New York, Chicago, Philadelphia, Pittsburgh, Cleveland, Dayton, Washington, D. C., Tulsa, Houston, Los Angeles. *Distributors in principal cities.*

TUBE-TURN
TRADE MARK
Welding Fittings

War Standard for Accuracy to Be Established

THE American Standards Association will develop an American War Standard for Cylindrical Fits, including gage specifications. This project was requested jointly by the Automotive Council for War Production, which represents more than 500 industrial concerns engaged in war production, and the War Production Board. These standards will be established to secure correct fits between the component parts of war equipment—even though the sizes of the parts may not be permitted to vary more than a few ten thousandths of an inch.

Strict Gage Control Essentials

Size control of machine parts requires not only maintenance of the manufacturing limits specified for the parts on their drawings, but also the establishment of specifications for the gagemaker's tolerances and the permissible wear to be allowed the gages used in checking the parts. One automobile company now making aircraft engines uses 100,000 gages for inspecting the engine parts and has to check the gages themselves at the rate of 5000 a day. Strict control is essential of the dimensions of gages in kinds of mechanisms whose parts require exacting fits such as the numerous components of an aircraft engine, yet, the war effort demands that such exacting work be turned out in large volume.

Uniform Gage Inspection

A uniform system of gaging inspection is necessary to secure interchange of exacting parts made by different firms. In the past these different firms have translated the parts limits given on the drawing into gage specifications by different methods, thus making interchange impossible. At a recent meeting of the Automotive Council for War Production in Detroit it was agreed that many of the difficulties which exist between various suppliers, subcontractors, and procurement agencies are due to the fact that individual manufacturers determine the supplemental data for their own interpretation of dimensions on drawings and that no system has ever been agreed upon among themselves.

A national standard on cylindrical fits will be immediately useful in the new manufacturing projects that may be undertaken during the remainder of the war and could find industry-wide application after the war.

A.S.M.E. Test Code for Coal Pulverizers

STANDARD practice for testing the performance characteristics of coal-pulverizing equipment is embodied in the recently completed A.S.M.E. Test Code for Coal Pulverizers. A limited number of printer's proofs are available on application to A.S.M.E. headquarters by those who have special interest in this equipment.

Individual Committee No. 4, responsible for the preparation of the code, consists of Edwards R. Fish, chairman, Alex D. Bailey, Max W. Benjamin, Bertram J. Cross, Martin Frisch, Philip H. Hardie, R. M. Hardgrove, Alfred Iddles, Elmer L. Lindseth, E. L. McDonald, Edwin B. Powell, R. Shellenberger, and Robert L. Spencer.

The code defines the practice of testing pulverizers for firing boiler furnaces, kilns, and industrial furnaces of various types to determine fineness of the pulverized product, capacity of the equipment, and power consumption under controlled operating conditions. Instruments and procedure for sampling coal, measuring air, coal, and power quantities, and instructions for operation of the equipment, are specified. Necessary calculations and corrections are detailed. A sample form provides for entering data and results. Illustrations indicate types of permissible sampling equipment.

Iowa Announces Summer Management Course

THE College of Engineering of the State University of Iowa, Iowa City, Ia., announces its fifth three-week summer course in management. This will be an intensive course intended for plant managers, foremen, industrial engineers, methods and time-study analysts, cost accountants, and office executives. It will be held especially for people in industry interested in comprehensive training in production planning, routing and scheduling of work, motion and time study, layout of manufacturing equipment, wage incentives, waste elimination, and related subjects. As development of better methods represents one of the most effective ways of increasing production the course stresses those fundamental principles and techniques which can be used to bring about the improvements of production methods.

With America now in its second year of war the University of Iowa is co-operating in a nation-wide program to accelerate the training of men needed for war industries.

For more detailed information, tuition fees, and living expenses, communications should be addressed to Prof. Ralph M. Barnes, 107 Engineering Building, University of Iowa, Iowa City, Iowa.

L. Austin Wright Honored by Rose Polytechnic

ON February 13, L. Austin Wright, general secretary of The Engineering Institute of Canada, was honored by Rose Polytechnic Institute, where he delivered the Commencement address, "Vocation or Profession."

The honorary degree of Doctor of Engineering was conferred on Mr. Wright on this occasion with the following citation:

LESLIE AUSTIN WRIGHT, MECHANICAL ENGINEER.

You were graduated from the University of Toronto and practiced your profession with signal success with municipalities, public services, and private corporations.

By reason of your attainments and your successes in your profession, you were chosen for the high position you now hold as General Secretary of The Engineering Institute of Canada and as editor of *The Engineering Journal*.

Because of your accomplishments in these fields and your wide acquaintance and friendships with the engineering fraternity, you were chosen to organize the Wartime Bureau of Technical Personnel at Ottawa under the auspices of the Department of Labor.

You held the honorable and difficult post of Assistant Director of National Selective Service of the Dominion of Canada, discharging its duties with honor to yourself and with devotion to your country.

You have many devoted friends among engineers in this country, and Rose Polytechnic Institute is honored in giving to you and in your acceptance from her, of an honorary degree.

I am happy to present you, the honored son of our beloved sister nation on this continent, for the honorary degree of Doctor of Engineering.

W. L. Batt Receives Bok Award

WM. LOREN BATT, past-president, A.S.M.E., president SKF Industries, and vice-chairman of the War Production Board, received on March 17 the Bok Award, founded in 1921 by Edward Bok, publisher, of Philadelphia. The award is made annually to the citizen who, in the opinion of the trustees of the award, performs or brings to its culmination in one year "a service calculated to advance the best and larger interests of Philadelphia." Mr. Batt's work on behalf of the war effort was the basis on which the award was made to him.

A.S.A. Standard for Graphs Issued

THE American Standards Association approved in January, 1943, American Standard, "Engineering and Scientific Graphs for Publications," sponsored by The American Society of Mechanical Engineers.

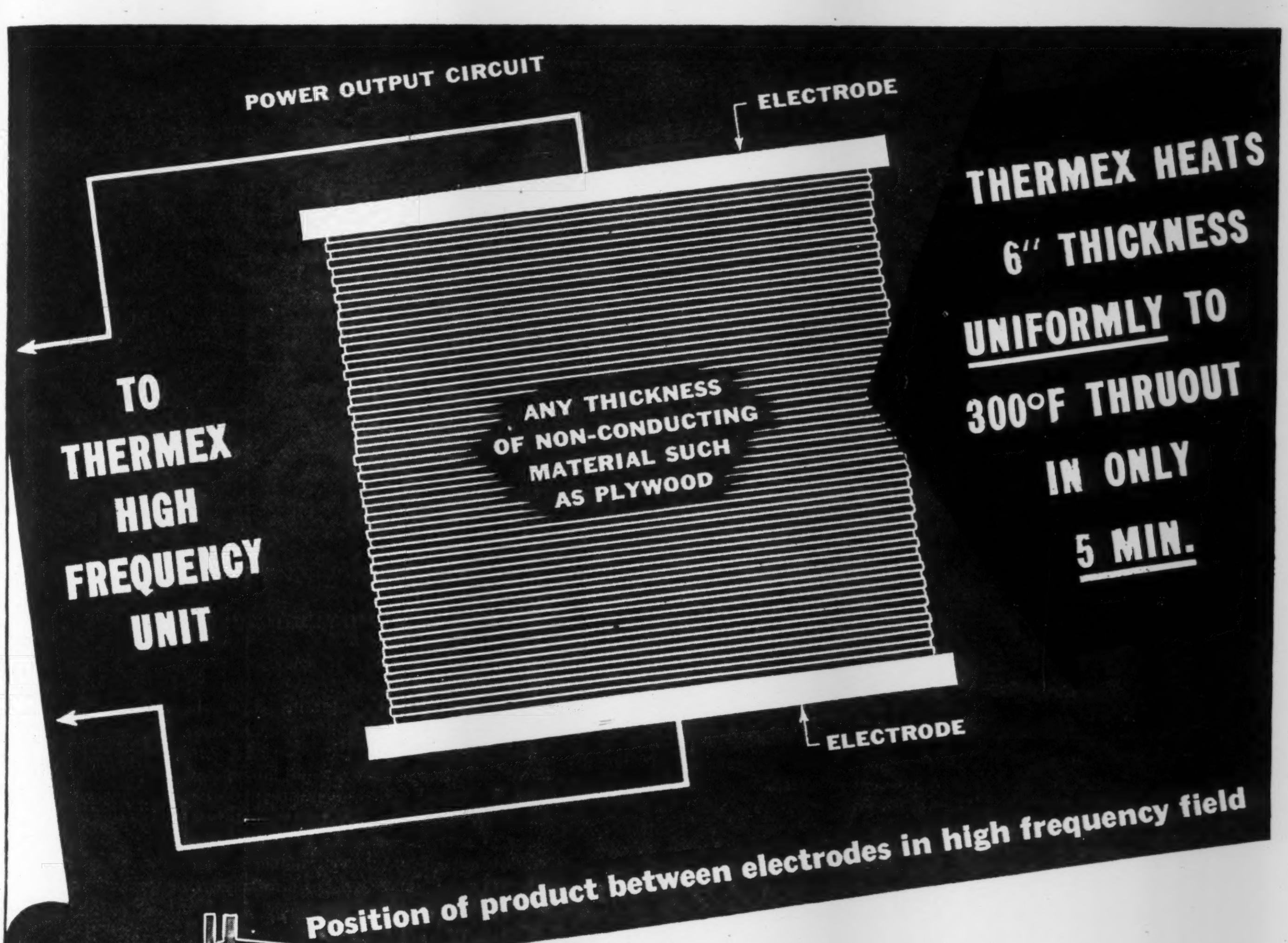
The recommended practices are intended for the guidance of authors and draftsmen who are preparing graphs for reproduction in engineering and technical publications. The standard covers the most common variety of engineering and scientific graphs, i.e., those that show the relationship between two variables in rectangular co-ordinates. Included in the Standard are: Design and layout; construction of the original graph to be used for reproduction; and the handling of finished illustrations. An appendix covers types of lettering templates and pens.

Copies of the Standard may be obtained from Publication Sales Department, The American Society of Mechanical Engineers, 29 West 39th St., New York, N. Y.

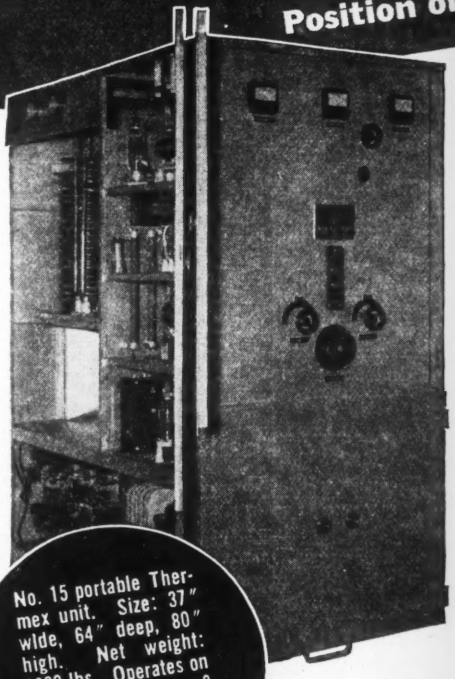
Eastern Photoelastic Conference, May 13–15

THE Seventeenth Semi-Annual Meeting of the Eastern Photoelasticity Conference and Symposium on Experimental Stress Analysis will be held on May 13–15, inclusive, at the Rackham Memorial Building, 100 Farnsworth Street, Detroit, Michigan, under the auspices of the Chrysler Institute of Engineering. All inquiries should be addressed to Mr. Lee R. Baker, Director of Graduate School, Chrysler Institute of Engineering, Highland Park, Michigan.

(*A.S.M.E. News continued on page 396*)


POWER OUTPUT CIRCUIT
ELECTRODE
TO THERMEX HIGH FREQUENCY UNIT
ANY THICKNESS OF NON-CONDUCTING MATERIAL SUCH AS PLYWOOD
ELECTRODE
THERMEX HEATS 6″ THICKNESS UNIFORMLY TO 300°F THRUOUT IN ONLY 5 MIN.

Position of product between electrodes in high frequency field



No. 15 portable Thermex unit. Size: 37″ wide, 64″ deep, 80″ high. Net weight: 3000 lbs. Operates on 220 volt, 60 cycle, 3 phase power service. Five standard sizes available.

Uniform, faster bonding or heat processing of any non-conducting material with Thermex!

Thermex high frequency equipment heats entire mass evenly . . . saves hours over other methods!

The above diagram shows how non-conducting materials may be bonded or heat processed *uniformly* and *quickly*. In this example, a six inch stack of non-conducting plywood panels is heated to 300° F. thruout in only five minutes with Thermex! At least ten hours is required to do the same job by any other method such as with hot plate conductive equipment.

With Thermex, heating is *absolutely* uniform regardless of the thickness of the mass or material. High frequency heating is ideal for practically every non-conducting material. Some of the many advantages of Thermex include: less handling of product, reduced labor cost, no variation in batch production, no surface damage, less danger of overheating, heating can be stopped instantly, no "hot plates" or steam required.

Find out how this remarkable new industrial heating equipment can help in your production. Send for free illustrated booklet today!

The GIRDLER CORPORATION
THERMEX HIGH FREQUENCY ELECTROSTATIC HEATING EQUIPMENT
THERMEX DIVISION · LOUISVILLE, KENTUCKY